Subject: ACS 547, Noise Control Applications - Module 2 Assignment

Date: February 23, 2025 (Submitted)

Problem 1 - Modal Behaviour of a Cylindrical Room

The Matlab code for this problem is listed in Appendix 1.

Problem 1a

Table 1 lists the ten lowest resonance mode orders for the room and the respective frequency.

Index	Mode (n_x, n_θ, n_r)	Frequency [Hz]
0	0, 0, 0	0
1	1, 0, 0	17.2
2	0, 1, 0	33.5
3	2, 0, 0	34.3
4	1, 1, 0	37.6
5	2, 1, 0	48.0
6	3, 0, 0	51.5
7	0, 2, 0	55.6
8	1, 2, 0	58.2
9	3, 1, 0	61.4
10	2, 2, 0	65.3

Table 1: Resonant modes of the cylindrical room.

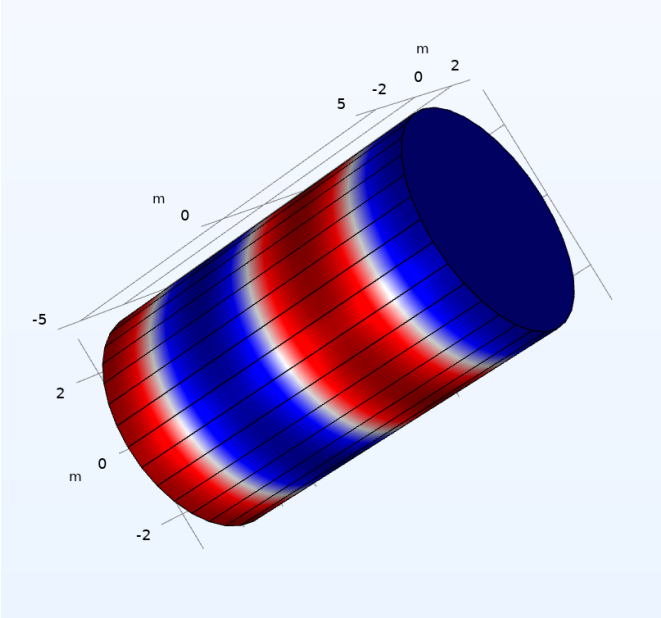
Problem 1b

The two closest modes are (3, 0, 0) and (0, 2, 0) with frequencies of 51.5 Hz and 55.6 Hz, respectively.

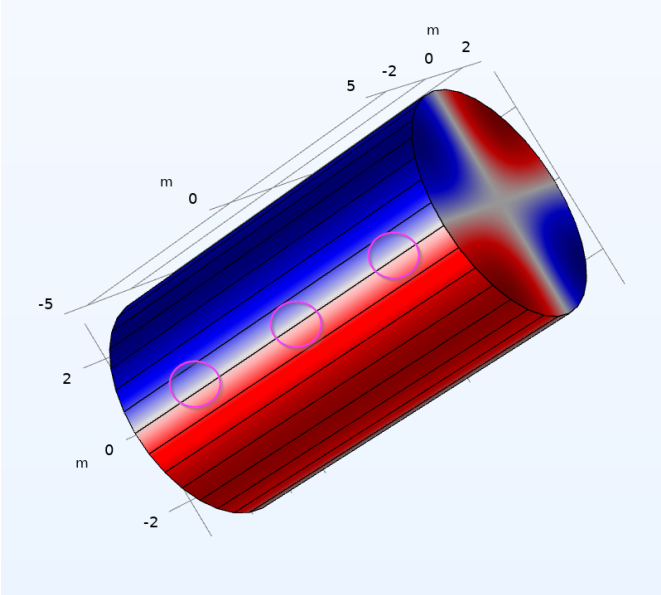
Problem 1c

Figure 1 illustrates the (3, 0, 0) and (0, 2, 0) modes. The white lines in each figure show the modal lines for that mode. **The machine can be placed where the modal lines for each mode overlap**. The figures were produced using the Room Eigenmode Simulator Version 1.1 software package.

The pink rings in Figure 1b indicate 3 possible places where the machine could be placed. These points coincide with the three modal planes shown in Figure 1a. Theoretically, there are an infinite number of places where the machine could be placed. However, placement would take into account practical considerations such as accessibility, etc.



(a) Mode (3, 0, 0)



(b) Mode (0, 2, 0)

Figure 1: Visualization of modes. (a.) Mode (3, 0, 0). (b.) Model (0, 2, 0). The pink circles in 1b illustrate a few modal line intersections where the machine could be placed.

Problem 2 - Sabine Room

The Matlab code for this problem is listed in Appendix 2.

Problem 2a

The reverberant field sound pressure level is approximately 98.3 dB SPL.

Problem 2b

Figure 2 shows the direct, reverberant, and total sound pressure levels for a 25 mW, 125 Hz, broadband, omnidirectional source placed centrally in the room (i.e. the directivity factor is 1).

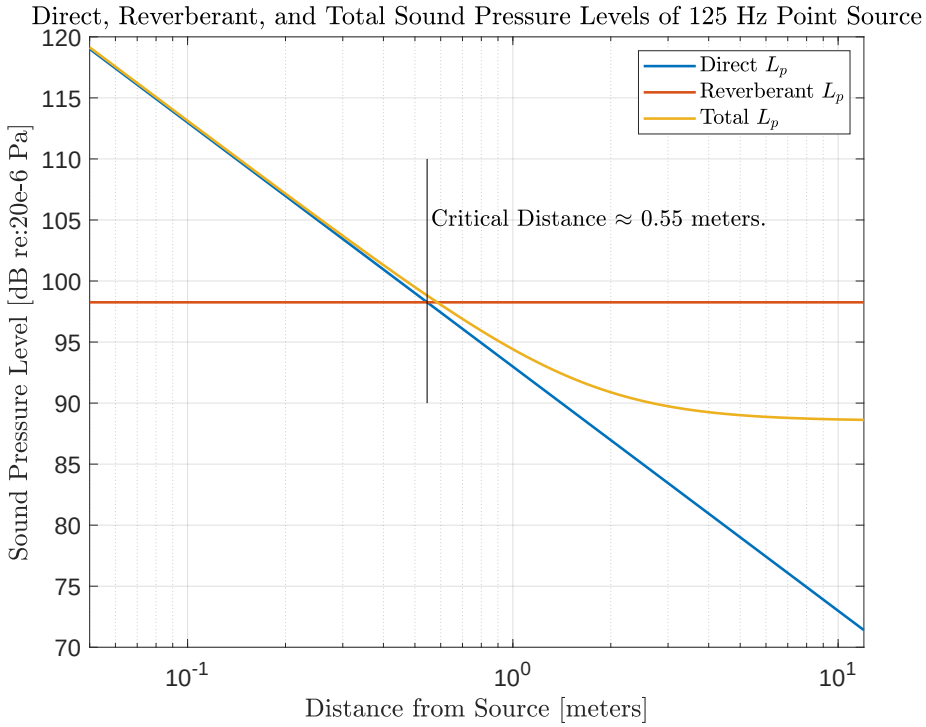


Figure 2: Sound levels for the room produced by a 25 mW, 125 Hz omnidirectional, broadband source.

Problem 3 - Transmission Loss Measurement

The Matlab code for this problem is listed in Appendix 3.

Figure 3 shows the average absorption per octave band based on the T60 data. The calibration plate isolates the receiver room and the absorption calculation does not consider the calibration plate.

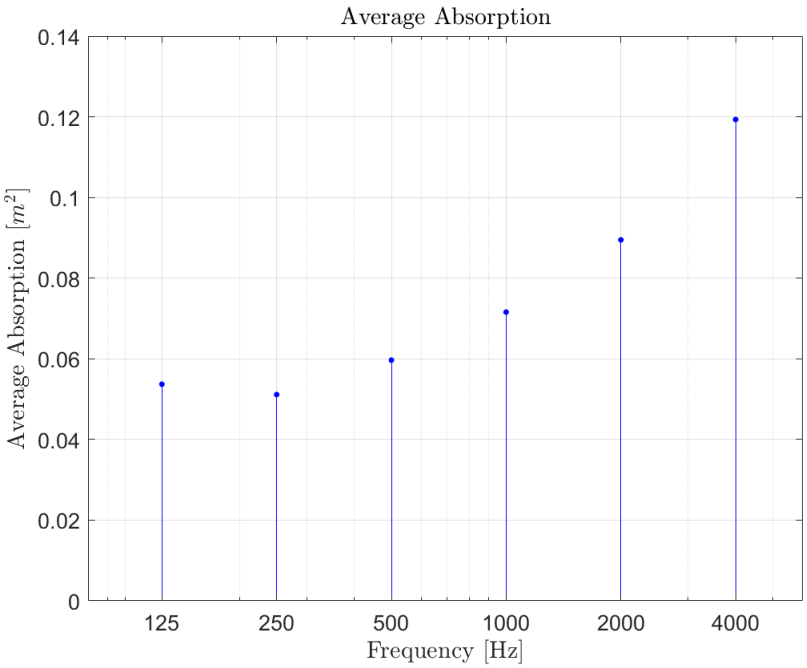


Figure 3: Average absorption per octave band.

Figure 4 shows the transmission loss per octave band.

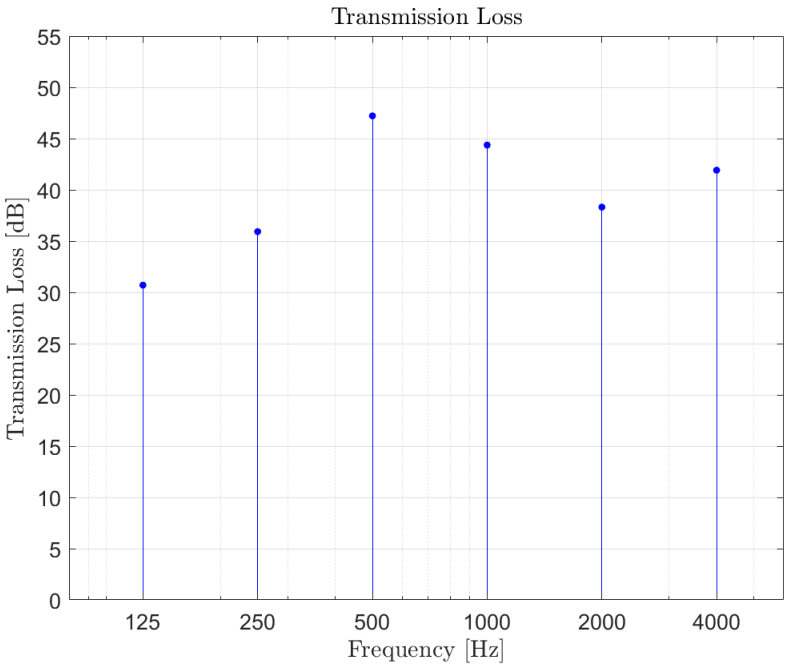


Figure 4: Transmission loss per octave band.

Problem 4 - Panel Transmission Loss

The Matlab code for this problem is listed in Appendix 4.

Problem 4a

Table 2 lists the Mach numbers for each pipe section. The flow rate is 0.017462 $\frac{m^3}{s}$.

Pipe	Area [m^2]	Mach Number [unitless]
Inlet	0.000507	-0.10047
Outlet	0.00811	-0.0062795

Table 2: Calculated Mach numbers.

Problem 4b

Figure **??** shows the transmission loss profiles.

The addition of flow to the intake system introduces a slight phase delay, a lower overall level of loss (approximately 22 dB), and greater loss at the dips. The phase delay is easier to see at respective dips in the loss profile.

i - Critical Frequency and Coincidence Frequency at 75°

ph

ii - Transmission Loss at Angle of Incidence of 75°

ph

iii - Transmission Loss for Angles of Incidence between 0-90°

ph

iv - Diffuse Transmission Loss

ph

Problem 4c

Problem 4d

i - Critical Frequency and Coincidence Frequency at 75°

ph

ii - Transmission Loss at Angle of Incidence of 75°

ph

vspace0.25cm

iii - Transmission Loss for Angles of Incidence between 0-90°

ph

iv - Diffuse Transmission Loss

Problem 5 - Large Enclosure Design

The Matlab code for this problem is listed in Appendix 6.

ph

Problem 6 - Close-fitting Enclosure Design

The Matlab code for this problem is listed in Appendix 6.

ph

1 Appendix - Matlab Code for Problem 1

```
1
2
3
4  %% Synopsis
5
6  % Problem 1 - Modal Behaviour of a Cylindrical Room
7
8
9
10 %% Environment
11
12 close all; clear; clc;
13 % restoredefaultpath;
14
15 % addpath( genpath( '' ), '-begin' );
16 addpath( genpath( './00 Support' ), '-begin' );
17
18 % set( 0, 'DefaultFigurePosition', [  400  400  900  400  ] ); % [ left bottom width height ]
19 set( 0, 'DefaultFigurePaperPositionMode', 'manual' );
20 set( 0, 'DefaultFigureWindowStyle', 'normal' );
21 set( 0, 'DefaultLineLineWidth', 1.5 );
22 set( 0, 'DefaultTextInterpreter', 'Latex' );
23
24 format ShortG;
25
26 pause( 1 );
27
28
29
30 %% Define Room
31
32 room.radius = 3;  % m
33 room.length = 10;  % m
34
35
36
37 %% Test Circular Mode Function
38
39 % psi = circular_mode_shape( 3, 1, 2, false );  % 3.7261 - CHECKED FROM CLASS (PLOT NOT CREATED)
40 % psi = circular_mode_shape( 3, 1, 2, true );  % 3.7261 - CHECKED FROM CLASS (PLOT CREATED)
41
42
43
44 %% Define Anonymous Function for the Natural Frequencies
45
46 h_natural_frequencies = @( c, nx, ntheta, nr, Lx, cylinder_radius, plot_flag )  (c/2) .* sqrt( (
       nx/Lx).^2  + (circular_mode_shape(nr, ntheta, cylinder_radius, plot_flag )/cylinder_radius)
       .^2 );
47
48
49
50 %% Calculate the Natural Frequencies
51
52 % The maximum number of radial modes is 5 (indexed from 0 to 4).
53 % The maximum number of angular modes is 8 (indexed from 0 to 7).
54
55 NX_SIZE = 20;
56 NTHETA_SIZE = 7;
57 NR_SIZE = 4;
58     natural_frequencies = nan( NX_SIZE, NTHETA_SIZE, NR_SIZE );
59
60 for nx = 0:1:NX_SIZE
61     for ntheta = 0:1:NTHETA_SIZE
62         for nr = 0:1:NR_SIZE
63             natural_frequencies( nx+1, ntheta+1, nr+1 ) = h_natural_frequencies( 343, nx, ntheta,
                   nr, 10, 3, false );
64         end
65     end
66 end
67
68
69
70 %% Part a - Find 10 Lowest Resonance Frequencies
71
72 NUMBER_OF_LOWEST_FREQUENCIES = 11;
```

```
    mode_indices =  ( 1:1:NUMBER_OF_LOWEST_FREQUENCIES ).';

[ sortedValues, sortedIndices ] = sort( natural_frequencies(:) );  % 21-by-8-by-5 -> 840 elements

smallestValues = sortedValues( 1:NUMBER_OF_LOWEST_FREQUENCIES );
    % [ mode_indices   round( smallestValues, 1 ) ]
    %
    % 1             0
    % 2          17.2
    % 3          33.5
    % 4          34.3
    % 5          37.6
    % 6          47.9
    % 7          51.5
    % 8          55.6
    % 9          58.2
    % 10          61.4
    % 11          65.3

smallestIndices = sortedIndices( 1:NUMBER_OF_LOWEST_FREQUENCIES );

[ x, y, z ] = ind2sub( size(natural_frequencies), smallestIndices );
    % ( [ x y z ] - 1 )

% Verify the calculated mode indices.
h_natural_frequencies( 343, 0, 0, 0, 10, 3, false );  % 0 Hz
h_natural_frequencies( 343, 1, 0, 0, 10, 3, false );  % 17.2 Hz
h_natural_frequencies( 343, 0, 1, 0, 10, 3, false );  % 33.5 Hz
h_natural_frequencies( 343, 2, 0, 0 , 10, 3, false );  % 34.3 Hz
h_natural_frequencies( 343, 1, 1, 0 , 10, 3, false );  % 37.6 Hz
h_natural_frequencies( 343, 2, 1, 0 , 10, 3, false );  % 48.0 Hz
h_natural_frequencies( 343, 3, 0, 0 , 10, 3, false );  % 51.5 Hz
h_natural_frequencies( 343, 0, 2, 0 , 10, 3, false );  % 55.6 Hz
h_natural_frequencies( 343, 1, 2, 0 , 10, 3, false );  % 58.2 Hz
h_natural_frequencies( 343, 3, 1, 0 , 10, 3, false );  % 61.4 Hz
h_natural_frequencies( 343, 2, 2, 0 , 10, 3, false );  % 65.3 Hz



%% Part b - Two

% [ (1:11).'  abs( smallestValues - 53 ) ]

temp = [ x y z ] - 1;  temp( 7:8, :, : )

h_natural_frequencies( 343, 3, 0, 0, 10, 3, false );  % 51.5 Hz, (3, 0, 0)
h_natural_frequencies( 343, 0, 2, 0, 10, 3, false );  % 55.6 Hz, (0, 2, 0)



%% Part c

% See the report.



%% Clean-up

if ( ~isempty( findobj( 'Type', 'figure' ) ) )
    monitors = get( 0, 'MonitorPositions' );
        if ( size( monitors, 1 ) == 1 )
            autoArrangeFigures( 2, 2, 1 );
        elseif ( 1 < size( monitors, 1 ) )
            autoArrangeFigures( 2, 2, 1 );
        end
end


fprintf( 1, '\n\n\n*** Processing Complete ***\n\n\n' );



%% Reference(s)

% https://www.mathworks.com/matlabcentral/answers/1883747-how-to-find-the-5-minimum-values-in-a-multidimensional-matrix-and-the-indices-to-which-these-entries
```

2 Appendix - Matlab Code for Problem 2

```
1
2
3
4  %% Synopsis
5
6  % Problem 2 - Sabine Room
7
8
9
10 %% Environment
11
12 close all; clear; clc;
13 % restoredefaultpath;
14
15 % addpath( genpath( '' ), '-begin' );
16 addpath( genpath( '../00 Support' ), '-begin' );
17
18 % set( 0, 'DefaultFigurePosition', [  400  400  900  400  ] ); % [ left bottom width height ]
19 set( 0, 'DefaultFigurePaperPositionMode', 'manual' );
20 set( 0, 'DefaultFigureWindowStyle', 'normal' );
21 set( 0, 'DefaultLineLineWidth', 1.5 );
22 set( 0, 'DefaultTextInterpreter', 'Latex' );
23
24 format ShortG;
25
26 pause( 1 );
27
28
29
30 %% Define Room
31
32 room.width = 8;  % m
33 room.length = 6;  % m
34 room.height = 3;  % m
35     room.volume = room.width * room.length * room.height;  % 144 m^3
36     room.area = 2*(room.width*room.height)  +  2*(room.length*room.height)  + 2*(room.width*room.
       length);  % 180 m^2
37
38 alpha_average_walls_and_floor = 0.05;  % For the walls and the floor.
39 alpha_average_ceiling = 0.15;  % For the ceiling.
40
41 % For the 125 Hz octave band.
42
43
44
45 %% Part a - Estimate the Reverberant Sound Pressure Level
46
47 Lw = 10*log10( 25e-3 / 1e-12 );  % 103.98 dB
48
49 average_absorption_coefficient = ( (room.width*room.length)*alpha_average_ceiling  +  (room.width
       *room.length  +  2*(room.width*room.height)  + 2*(room.length*room.height) )*
       alpha_average_walls_and_floor ) / room.area;  % 0.076667 unitless
50
51 room_constant = room.area * average_absorption_coefficient / ( 1 - average_absorption_coefficient
       );  % 14.9 m^2 or Sabin
52
53
54 sound_pressure_level = Lw + 10*log10( 4 / room_constant );  % 98.3 dB
55
56
57
58 %% Part b - Calculate the Critical Distance
59
60 D0 = 1;
61
62 r = 0:0.05:12;  % m
63
64 h_Lp_direct = @( Lw, D0, r )  Lw + 10*log10( D0./(4.*pi.*r.^2) );
65 h_Lp_reverberant = @( Lw, room_constant )  Lw + 10*log10( 4 ./ room_constant );
66 %
67 h_Lp_net = @( Lw, D0, r, room_constant )  Lw + 10*log10( D0./(4.*pi.*r.^2) + 4/room_constant ) +
       10*log10( 343*1.2/400 );
68
69
70 figure( ); ...
```

```
    h1 = plot( r, h_Lp_direct( Lw, D0, r ) );  hold on;
    h2 = plot( r, ones( size(r) ).*h_Lp_reverberant( Lw, room_constant) );
    h3 = plot( r, h_Lp_net( Lw, D0, r, room.volume ));  grid on;
        legend( [ h1, h2 h3 ], { 'Direct $L_p$', 'Reverberant $L_p$', 'Total $L_p$' }, '
            Interpreter', 'Latex' );
    %
    text( 0.56, 105, 'Critical Distance $\approx$ 0.55 meters.', 'Interpreter', 'Latex' );
        line( [ 0.545 0.545 ], [ 90 110 ], 'Color', 'k', 'LineWidth', 0.6 );
    %
    xlabel( 'Distance from Source [meters]' );  ylabel( 'Sound Pressure Level [dB re:20e-6 Pa]' )
        ;
    title( 'Direct, Reverberant, and Total Sound Pressure Levels of 125 Hz Point Source' );
    %
    set( gca, 'XScale', 'log' );


% Estimate the critical distance (see page 84 of "06-Indoors.pdf" notes for ACS 537).
rc = 0.141 * sqrt( D0 * room_constant );  % 0.5451 meters

return

%% Clean-up

if ( ~isempty( findobj( 'Type', 'figure' ) ) )
    monitors = get( 0, 'MonitorPositions' );
        if ( size( monitors, 1 ) == 1 )
            autoArrangeFigures( 2, 2, 1 );
        elseif ( 1 < size( monitors, 1 ) )
            autoArrangeFigures( 2, 2, 1 );
        end
end


fprintf( 1, '\n\n\n*** Processing Complete ***\n\n\n' );



%% Reference(s)
```

3 Appendix - Matlab Code for Problem 3

```
1
2
3
4  %% Synopsis
5
6  % Question 3 - Transmission Loss Measurement
7
8
9  % Note(s):
10 %
11 %   1.)  Lp1 depends on the transmission loss.
12 %
13 %       If the transmission loss is low, then more energy goes to room 2 (i.e., the receiver room
       ).
14 %
15 %       The noise reduction from the source room to the receiver room.
16 %
17 %       Adding the barrier will change the level in the source room.  Typically making the sound
       level higher in the source room.
18
19
20
21 %% Environment
22
23 close all; clear; clc;
24 % restoredefaultpath;
25
26 % addpath( genpath( '' ), '-begin' );
27 addpath( genpath( '../00 Support' ), '-begin' );
28
29 % set( 0, 'DefaultFigurePosition', [  400  400  900  400  ] ); % [ left bottom width height ]
30 set( 0, 'DefaultFigurePaperPositionMode', 'manual' );
31 set( 0, 'DefaultFigureWindowStyle', 'normal' );
32 set( 0, 'DefaultLineLineWidth', 1.2 );
33 set( 0, 'DefaultLineMarker', 'x' );
34 set( 0, 'DefaultLineMarkerSize', 15 );
35 % set( 0, 'DefaultAxesLineStyleOrder', { '-' '--o' '+' } );
36 set( 0, 'DefaultTextInterpreter', 'Latex' );
37
38 format ShortG;
39
40 pause( 1 );
41
42
43
44 %% Dimensions of Rooms and Panel
45
46 room.length = 4;  % m
47 room.width = 4;  % m
48 room.height = 4;  % m
49     room.volume = room.length * room.width * room.height;  % 64 m^3
50     room.area = 2*(room.length * room.width) + 2*(room.length * room.height) + 2*(room.width *
           room.height);  % 96 m^2
51
52 panel.width = 0.8;  % m
53 panel.height = 0.8;  % m
54     panel.area = panel.width * panel.height;  % 0.64 m^2
55
56 c = 343;  % m/s
57
58
59
60 %% Measurement Data
61
62 octave_band_frequencies = [ 125  250  500  1000  2000  4000 ].';  % Hz
63 T60 = [ 2.0  2.1  1.8  1.5  1.2  0.9 ].';  % seconds
64 spl.source_room = [ 90  95  103  105  100  93 ].';  % dB re: 20e-6 Pa
65 spl.receiver_room = [ 50  50  46  50  50  38 ].';  % dB re: 20e-6 Pa
66     % [ octave_band_frequencies  T60  spl.source_room  spl.receiver_room  (spl.source_room - spl.
           receiver_room) ]
67
68
69
70 %% Calculate Average Absorption in the Receiver Room using Reverberation Time Measurements
71
```

```
72 average_absorption = @( volume, area, c, T60 )  ( 55.25 .* volume ) ./ ( area .* c .* T60 );
73
74 receiver_room.average_absorption = average_absorption( room.volume, room.area, c, T60 );
75
76 % Assumption:  Calibration panel has very high transmission loss.
77
78 figure( ); ...
79     stem( octave_band_frequencies, receiver_room.average_absorption, 'Marker', '.', 'MarkerSize',
         12, 'Color', 'b' );  grid on;
80     xlabel( 'Frequency [Hz]' );  ylabel( 'Average Absorption [$m^2$]' );
81     title( 'Average Absorption' );
82     %
83     xticks( octave_band_frequencies );  xticklabels( num2cell( octave_band_frequencies ) );
84     set( gca, 'XScale', 'log' );
85     xlim( [ 80 6e3 ] );  ylim( [ 0 0.14 ] );
86
87
88
89 %% Calculate the Receiver Room Constant
90
91 % The calibration plate isolates the receiver room.
92
93 % The receiver room does not consider the calibration plate.
94
95 room_constant = @( average_absorption, area )  ( average_absorption * area ) ./ ( 1 -
       average_absorption );  % Unitless
96
97 receiver_room.room_constant = room_constant( receiver_room.average_absorption, room.area );
98
99
100
101 %% Calculate the Transmission Loss in Each Octave Band
102
103 transmission_coefficient = @( receiver_room_pressure, source_room_pressure, panel_area,
       receiver_room_constant )  ( ( receiver_room_pressure ./ source_room_pressure ) .*
       receiver_room_constant ) ./ panel_area;
104
105 tau = transmission_coefficient( 10.^(spl.receiver_room./10)*20e-6, 10.^(spl.source_room/10)*20e
       -6, panel.area, receiver_room.room_constant );
106
107 TL = -10*log10( tau );
108
109 figure( ); ...
110     stem( octave_band_frequencies, TL, '.', 'MarkerSize', 15, 'Color', 'b' );  grid on;
111     xlabel( 'Frequency [Hz]' );  ylabel( 'Transmission Loss [dB]' );
112     title( 'Transmission Loss' );
113     %
114     xticks( octave_band_frequencies );  xticklabels( num2cell( octave_band_frequencies ) );
115     set( gca, 'XScale', 'log' );
116     xlim( [ 80 6e3 ] );  ylim( [ 0 55 ] );
117
118 return
119
120 %% Clean-up
121
122 if ( ~isempty( findobj( 'Type', 'figure' ) ) )
123     monitors = get( 0, 'MonitorPositions' );
124         if ( size( monitors, 1 ) == 1 )
125             autoArrangeFigures( 2, 2, 1 );
126         elseif ( 1 < size( monitors, 1 ) )
127             autoArrangeFigures( 2, 2, 1 );
128         end
129 end
130
131
132 fprintf( 1, '\n\n\n*** Processing Complete ***\n\n\n' );
133
134
135
136 %% Reference(s)
```

4 Appendix - Matlab Code for Problem 4

```
1
2
3
4  %% Synopsis
5
6  % Slide 8 - Noise Reduction and Transmission Loss
7
8
9
10 %% Environment
11
12 % close all; clear; clc;
13 % restoredefaultpath;
14
15 % addpath( genpath( '' ), '-begin' );
16 addpath( genpath( '../40 Assignments/00 Support' ), '-begin' );
17
18 % set( 0, 'DefaultFigurePosition', [  400  400  900  400  ] ); % [ left bottom width height ]
19 set( 0, 'DefaultFigurePaperPositionMode', 'manual' );
20 set( 0, 'DefaultFigureWindowStyle', 'normal' );
21 set( 0, 'DefaultLineLineWidth', 0.8 );
22 set( 0, 'DefaultTextInterpreter', 'Latex' );
23
24 format ShortG;
25
26 pause( 1 );
27
28 PRINT_FIGURES = 0;
29
30
31
32 %% Parameters
33
34 c = 343;  % m/s
35 rho0 = 1.21;  % kg
36
37 panel.length = 80e-2;  % meters
38 %
39 panel.E = 200e9;  % Pascals
40 panel.density = 7800;  % kg / m^3
41 panel.v = 0.29;  % Poisson's Ratio (unitless)
42 panel.thickness = 1.2e-3;  % m
43 panel.eta = 0.001;  % Loss factor (unitless)
44
45
46
47 %% Panel Data
48
49 octave_band_frequencies = [ 63  125  250  500  1000  2000  4000  8000 ].';  % Hz
50 TL = [ 9  14  21  27  32  37  43  42 ].';  % dB
51
52
53 % figure( ); ...
54 %     stem( octave_band_frequencies, TL, 'LineWidth', 0.5, 'Marker', 'o', 'MarkerSize', 8, '
       MarkerEdgeColor', 'b', 'MarkerFaceColor', 'r' );  grid on;
55 %     xlabel( 'Frequency [Hz] ' );  ylabel( 'Transmission Loss [dB]' );
56 %     title( 'Measured Panel Transmission Losses' );
57 %     set( gca, 'XScale', 'log' );
58 %     axis( [ 40 12e3 -5 45] );
59
60
61
62 %% Problem 4a - Infinite, Rigid Panel Model with Normal Incidence
63
64 D = ( panel.E * panel.thickness.^3 ) / ( 12 * ( 1 - panel.v^2 ) );  % 31.4
65
66 % From lecture 9 on Wednesday, February 12, 2025, the equivalent bending
67 % moment of the panel is a half-wavelength.
68 %
69 wavelength = 2 * panel.length;  % 1.6 meters
70
71 ms = panel.density * panel.thickness;
72
73 wo = pi^2 / panel.length * sqrt( D / ms );
74      s = wo^2 * ms;
```

```
75
76 h_tau_infinite_rigid_panel = @( f, wo, ms, s, rho0, c, eta)  4 ./ ( ( (2*pi.*f*ms - s./(2*pi.*f))
       ./ (rho0 * c) ).^2  +  ( (wo*ms*eta) ./ (rho0*c) + 2 ).^2 );
77
78 h_tau_infinite_rigid_panel_side_materials = @( f, wo, ms, s, rho0, c, eta, n )  (4*n) ./ ( ( (2*
       pi.*f*ms - s./(2*pi.*f)) ./ (rho0 * c) ).^2  +  ( (wo*ms*eta) ./ (rho0*c) + n + 1 ).^2 );
79
80
81
82 %% Problem 4b - Infinite, Flexible Panel Model with Random Incidence
83
84 % Panel has bending waves.
85
86
87 h_tau_term1 = @( rho0, c, phi )  ( 2*rho0*c*secd(phi) ).^2;  % Checked
88 h_tau_term2 = @( rho0, c, phi, D, eta, f )  ( 2*rho0*c*secd(phi) + (D*eta*(2*pi.*f./c).^4)./(2*pi
       .*f) .* sind(phi).^4 ).^2;  % Checked
89 h_tau_term3 = @( f, ms, D, phi )  ( 2*pi.*f*ms  -  D*(2*pi.*f./c).^4./(2*pi.*f) .* sind(phi).^4 )
       .^2;  % Checked
90
91
92 h_tau_infinite_flexible_panel = @( f, rho0, c, phi, D, eta )  ( 2*rho0.*c*secd(phi)).^2 ./ ( (2*
       rho0.*c*secd(phi) + D*eta*(2*pi.*f./c).^4./(2*pi.*f)*sind(phi)^4).^2  +  ...
93     (2*pi.*f*ms - D*(2*pi.*f./c).^4./(2*pi.*f)*sind(phi)^4).^2 );
94
95 % return
96
97 %% Plot Data and Model - Air on Both Sides
98
99 % 75 degrees from normal to panel.
100
101 h_c_bending_wave = @( D, f, ms )  ( (D*(2*pi.*f).^2) ./ ms ).^0.25;
102 %
103 %   Proportional to the square-root of frequency.
104 %
105 %       Small wavelenths (high frequencies;  arrive first) travel faster than long wavelength (
        low frequencies;  arrive later).
106
107 phi = 75;
108     h_coincidence_frequency =  @( ms, D, c, phi )  1./(2*pi) * sqrt( ms / D ) .* ( c ./ sind( phi
            )).^2;  % 10,949 Hz
109
110     h_coincidence_frequency( ms, D, c, phi );  % 10,949 Hz
111
112     [ (0:15:90).'  h_coincidence_frequency( ms, D, c, [ 0:15:90 ] ).' ];
113
114
115     critical_frequency =  1./(2*pi) .* sqrt( ms / D ) .* ( c / sind( 90 )).^2  % 10,216 Hz
116         critical_frequency_verify_1 = c^2 / (2*pi) * sqrt( ms / D );  % lowest coincidence
                frequency
117         critical_frequency_verify_2 = c^2 / ( 1.8 * panel.thickness * sqrt( panel.E / ( panel.
                density * ( 1 - panel.v^2) ) ) );
118
119
120
121
122 % f = 1e-2:1e-2:40e3;
123 f = 1e-2:1:100e3;
124
125
126 eta = panel.eta;
127
128 phi_set = 0:10:90;
129
130 [ phi_set.'  h_coincidence_frequency( ms, D, c, phi_set ).' ]
131
132 t_set = [ ];
133
134
135 h1 = figure( ); ...
136
137     hold on;
138     % stem( octave_band_frequencies ./ (wo / (2*pi) ), TL, 'LineWidth', 0.5, 'Marker', 'o', '
            MarkerSize', 8, 'MarkerEdgeColor', 'b', 'MarkerFaceColor', 'r' );  hold on;
139     stem( octave_band_frequencies, TL, 'LineWidth', 0.5, 'Marker', 'o', 'MarkerSize', 8, '
            MarkerEdgeColor', 'b', 'MarkerFaceColor', 'r' );  hold on;
140     line( [ 16e3 16e3 ], [ 0 65 ], 'Color', 'c' );
141     %
```

```
142     % plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s, rho0, c,
            panel.eta ) ), 'LineStyle', '-' );
143     plot( f, -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s, rho0, c, panel.eta ) ), '
            LineStyle', '-' );
144     %
145
146     for phi = phi_set
147         % plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_term1( rho0, c, phi ) ./ ( h_tau_term2(
                rho0, c, phi, D, eta, f ) + h_tau_term3( f, ms ,D, phi ) ) ), 'Color', 'r', '
                LineStyle', '-', 'Marker', 'none' );
148         % plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_flexible_panel( f, rho0, c, phi, D
                , panel.eta ) ), 'LineStyle', '--', 'Marker', 'none' );
149         plot( f, -10*log10( h_tau_term1( rho0, c, phi ) ./ ( h_tau_term2( rho0, c, phi, D, eta, f
                ) + h_tau_term3( f, ms ,D, phi ) ) ), 'Color', 'r', 'LineStyle', '-', 'Marker', '
                none' );
150         % plot( f, -10*log10( h_tau_infinite_flexible_panel( f, rho0, c, phi, D, panel.eta ) ), '
                LineStyle', '--', 'Marker', 'none' );
151
152         t_set = [ t_set;  h_tau_infinite_flexible_panel( f, rho0, c, phi, D, panel.eta ) ];
153
154     end
155
156     grid on;
157
158     xlabel( 'Frequency [$\frac{\omega}{\omega_o}$] ' );  ylabel( 'Transmission Loss [dB]' );
159     title( 'Measured Panel Transmission Losses' );
160     set( gca, 'XScale', 'log' );
161     axis( [ 2e-3 100e3 -5 70 ] );
162
163     close( h1 );
164
165
166 N_phi = size( t_set, 1 );
167
168 temp1 = t_set;
169 temp2 = sind( 2*phi_set ).';
170 % temp2 = sind( phi_set ).';
171
172 temp3 = t_set .* repmat( temp2, 1, size( temp1, 2 ) );
173
174 tau_d = 1/N_phi .* nansum( temp3, 1 );
175
176 tau_d_verify = nanmean( t_set .* temp2, 1 );
177
178
179
180 h2 = figure( ); ...
181
182     hold on;
183
184     stem( octave_band_frequencies, TL, 'LineWidth', 0.5, 'Marker', 'o', 'MarkerSize', 8, '
            MarkerEdgeColor', 'b', 'MarkerFaceColor', 'r' );  hold on;
185
186     line( [ 16e3 16e3 ], [ 0 65 ], 'Color', 'b', 'LineWidth', 1.5 );
187
188     plot( f, -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s, rho0, c, panel.eta ) ), '
            LineStyle', '-' );
189
190     for phi = phi_set
191         plot( f, -10*log10( h_tau_term1( rho0, c, phi ) ./ ( h_tau_term2( rho0, c, phi, D, eta, f
                ) + h_tau_term3( f, ms ,D, phi ) ) ), 'Color', 'r', 'LineStyle', '-', 'Marker', '
                none' );
192         % plot( f, -10*log10( h_tau_infinite_flexible_panel( f, rho0, c, phi, D, panel.eta ) ), '
                LineStyle', '--', 'Marker', 'none' );
193     end
194
195     plot( f, -10*log10( tau_d ), 'LineStyle', '-', 'Marker', 'none', 'Color', 'm', 'LineWidth',
            1.2 );
196     plot( f, -10*log10( tau_d_verify ), 'LineStyle', '-', 'Marker', 'none', 'Color', 'k', '
            LineWidth', 1.2 );
197
198
199     plot( f, -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s, rho0, c, panel.eta ) ./ panel.
            eta * ( 4*panel.length / ( panel.length^2 * critical_frequency ) ) ), 'LineStyle', '-', '
            Marker', 'none', 'Color', 'k', 'LineWidth', 1.2 );
200
201     grid on;
202
```

```
203     xlabel( 'Frequency [$\frac{\omega}{\omega_o}$] ' );  ylabel( 'Transmission Loss [dB]' );
204     title( 'Measured Panel Transmission Losses' );
205     set( gca, 'XScale', 'log' );
206     axis( [ 2e-3 200e3 -5 90 ] );
207
208     close( h2 );
209
210 % return
211
212 %% Final Plot
213
214 figure( ); ...
215
216     hold on;
217
218     stem( octave_band_frequencies, TL, 'LineWidth', 0.5, 'Marker', 'o', 'MarkerSize', 8, '
        MarkerEdgeColor', 'b', 'MarkerFaceColor', 'r' );  hold on;
219
220     plot( f, -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s, rho0, c, panel.eta ) ), '
        LineStyle', '-' );
221
222     plot( f, -10*log10( tau_d ), 'LineStyle', '-', 'Marker', 'none', 'Color', 'm', 'LineWidth',
        1.2 );
223     % plot( f, -10*log10( tau_d_verify ), 'LineStyle', '-', 'Marker', 'none', 'Color', 'k', '
        LineWidth', 1.2 );
224
225     plot( f, -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s, rho0, c, panel.eta ) ./(200*
        panel.eta) * ( 4*panel.length / ( panel.length^2 * critical_frequency ) ) ), 'LineStyle',
         '-', 'Marker', 'none', 'Color', 'k', 'LineWidth', 1.2 );
226
227     line( [ 16e3 16e3 ], [ 0 65 ], 'Color', 'b', 'LineWidth', 1.5 );
228
229     grid on;
230
231     legend( ...
232         'Target Transmission Loss', ...
233         'Infinite Rigid Panel', ...
234         'Infinite Flexible Panel with Diffuse Incidence', ...
235         'Finite Flexible Panel Model' );
236
237     xlabel( 'Frequency [$\frac{\omega}{\omega_o}$] ' );  ylabel( 'Transmission Loss [dB]' );
238     title( 'Measured Panel Transmission Losses' );
239     set( gca, 'XScale', 'log' );
240     axis( [ 2e-3 200e3 -5 90 ] );
241
242
243
244 %% Plot Data and Model - Different Side Materials
245
246 % f = 1e-2:1e-2:20e3;
247 %
248 % phi = 15;
249 % eta = panel.eta;
250 %
251 %
252 % figure( ); ...
253 %     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel_side_materials( f, wo, ms,
      s, rho0, c, panel.eta, 1 ) ), 'LineStyle', '-' );  hold on;
254 %     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel_side_materials( f, wo, ms,
      s, rho0, c, panel.eta, 1/3600 ) ), 'LineStyle', '-' );
255 %     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel_side_materials( f, wo, ms,
      s, rho0, c, panel.eta, 3600 ) ), 'LineStyle', '-' );  grid on;
256 %         %
257 %         legend( ...
258 %             'Same Fluid', ...
259 %             'Water to Air', ...
260 %             'Air to Water', ...
261 %             'Location', 'North' );
262 %     %
263 %     xlabel( 'Frequency [$\frac{\omega}{\omega_o}$] ' );  ylabel( 'Transmission Loss [dB]' );
264 %     title( 'Measured Panel Transmission Losses' );
265 %     set( gca, 'XScale', 'log' );
266 %     % axis( [ 40 12e3 -5 45] );
267
268
269
270 %% Change is Stiffness
271
```

```
% figure( ); ...
%     stem( octave_band_frequencies ./ (wo / (2*pi) ), TL, 'LineWidth', 0.5, 'Marker', 'o', '
    MarkerSize', 8, 'MarkerEdgeColor', 'b', 'MarkerFaceColor', 'r' );  hold on;
%     %
%     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s, rho0, c,
    panel.eta ) ), 'LineStyle', '-' );
%     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s*100, rho0, c
    , panel.eta ) ), 'LineStyle', '--' );
%     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s*1e-2, rho0,
    c, panel.eta ) ), 'LineStyle', '--' );
%         %
%         legend( ...
%             'Target TL Values', ...
%             'Infinite Rigid Panel with Normal Incidence Sound', ...
%             'Infinite Rigid Panel with Normal Incidence Sound (s * 100)', ...
%             'Infinite Rigid Panel with Normal Incidence Sound (s / 100)', ...
%             'Location', 'North' );
%     %
%     xlabel( 'Frequency [$\frac{\omega}{\omega_o}$] ' );  ylabel( 'Transmission Loss [dB]' );
%     title( 'Measured Panel Transmission Losses - Change in Stiffness' );
%     set( gca, 'XScale', 'log' );
%     % axis( [ 40 12e3 -5 45] );



%% Change in Mass

% figure( ); ...
%     stem( octave_band_frequencies ./ (wo / (2*pi) ), TL, 'LineWidth', 0.5, 'Marker', 'o', '
    MarkerSize', 8, 'MarkerEdgeColor', 'b', 'MarkerFaceColor', 'r' );  hold on;
%     %
%     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel( f, wo, ms*100, s, rho0, c
    , panel.eta ) ), 'LineStyle', '-' );
%     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s, rho0, c,
    panel.eta ) ), 'LineStyle', '-' );
%     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel( f, wo, ms*1e-2, s, rho0,
    c, panel.eta ) ), 'LineStyle', '-' );
%         %
%         legend( ...
%             'Target TL Values', ...
%             'Infinite Rigid Panel with Normal Incidence Sound', ...
%             'Infinite Rigid Panel with Normal Incidence Sound (s * 100)', ...
%             'Infinite Rigid Panel with Normal Incidence Sound (s / 100)', ...
%             'Location', 'North' );
%     %
%     xlabel( 'Frequency [$\frac{\omega}{\omega_o}$] ' );  ylabel( 'Transmission Loss [dB]' );
%     title( 'Measured Panel Transmission Losses - Change in Mass' );
%     set( gca, 'XScale', 'log' );
%     % axis( [ 40 12e3 -5 45] );



%% Change in Loss Factor

% figure( ); ...
%     stem( octave_band_frequencies ./ (wo / (2*pi) ), TL, 'LineWidth', 0.5, 'Marker', 'o', '
    MarkerSize', 8, 'MarkerEdgeColor', 'b', 'MarkerFaceColor', 'r' );  hold on;
%     %
%     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s, rho0, c,
    panel.eta ) ), 'LineStyle', '-' );
%     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s, rho0, c,
    panel.eta*1e2 ) ), 'LineStyle', ':' );
%     plot( f ./ (wo / (2*pi) ), -10*log10( h_tau_infinite_rigid_panel( f, wo, ms, s, rho0, c,
    panel.eta*1e-2 ) ), 'LineStyle', ':' );
%         %
%         legend( ...
%             'Target TL Values', ...
%             'Infinite Rigid Panel with Normal Incidence Sound', ...
%             'Infinite Rigid Panel with Normal Incidence Sound (eta * 100)', ...
%             'Infinite Rigid Panel with Normal Incidence Sound (eta / 100)', ...
%             'Location', 'North' );
%     %
%     xlabel( 'Frequency [$\frac{\omega}{\omega_o}$] ' );  ylabel( 'Transmission Loss [dB]' );
%     title( 'Measured Panel Transmission Losses - Change in Loss Factor' );
%     set( gca, 'XScale', 'log', 'YScale', 'log' );
%     % axis( [ 40 12e3 -5 45] );


```

```
338
339 %% Clean-up
340
341 % return
342
343 if ( ~isempty( findobj( 'Type', 'figure' ) ) )
344     monitors = get( 0, 'MonitorPositions' );
345         if ( size( monitors, 1 ) == 1 )
346             autoArrangeFigures( 2, 2, 1 );
347         elseif ( 1 < size( monitors, 1 ) )
348             autoArrangeFigures( 2, 2, 1 );
349         end
350 end
351
352
353 fprintf( 1, '\n\n\n*** Processing Complete ***\n\n\n' );
354
355
356
357 %% Reference(s)
```

5 Appendix - Matlab Code for Problem 5

```
1
2
3
4  %% Synopsis
5
6  % Slide 8 - Noise Reduction and Transmission Loss
7
8  % Volume of the enclosure is much bigger than the machine.  Diffuse sound field in the enclosure.
9
10
11
12 %% Environment
13
14 % close all; clear; clc;
15 % restoredefaultpath;
16
17 % addpath( genpath( '' ), '-begin' );
18 addpath( genpath( '../40 Assignments/00 Support' ), '-begin' );
19
20 % set( 0, 'DefaultFigurePosition', [  400  400  900  400  ] ); % [ left bottom width height ]
21 set( 0, 'DefaultFigurePaperPositionMode', 'manual' );
22 set( 0, 'DefaultFigureWindowStyle', 'normal' );
23 set( 0, 'DefaultLineLineWidth', 0.8 );
24 set( 0, 'DefaultTextInterpreter', 'Latex' );
25
26 format ShortG;
27
28 pause( 1 );
29
30 PRINT_FIGURES = 0;
31
32
33
34 %% Define Machine
35
36 machine.area = 3;  % m^2
37 machine.absorption = 0.07;  % Sabine
38 machine.D = 1;  % Unitless - In air.
39
40 machine.distance = 10;  % m
41
42
43
44 %% Data
45
46 octave_band_frequencies = [ 250  500  1000  2000  4000 ].';  % Hz
47 Lw = [ 105  115  106  108  119 ].';  % dB re: 1 pW
48     % [ octave_band_frequencies  Lw ]
49
50 % figure( ); ...
51 %     h1 = stem( octave_band_frequencies, Lw, 'Marker', '.', 'MarkerSize', 12, 'Color', 'r' );
       hold on;
52 %     h2 = line( [ 2e2 5e3 ], [ 30 30 ] );  grid on;
53 %         legend( [ h1 h2 ], 'Current Sound Pressure Levels', 'Target Sound Pressure Level', '
       Location', 'North' );
54 %     xlabel( 'Frequency [Hz]' );  ylabel( 'Sound Pressure Level [dB re: 20e-6 Pa]' );
55 %     title( 'Sound Power Level Versus Octave Band Center Frequency' );
56 %     %
57 %     axis( [ 150 6e3  0 140 ] );
58 %     set( gca, 'XScale', 'log' );
59
60
61
62 %% Per Octave Band Insertion Loss
63
64 Lp_10_meters = Lw  +  10*log10( machine.D /( 4 * pi * machine.distance^2 ) );  % dB re: 20e-6 Pa
       % [ octave_band_frequencies  Lp_10_meters ]
65 %
66 %  The value of R is infinite.  The machine is outside in open air.
67
68 octave_band_IL = Lp_10_meters - 30;
69     % [ octave_band_frequencies  octave_band_IL ]
70
71
72
73
```

```
%% Anonymous Function for Insertion Loss

h_IL_large = @( Sw, alpha_w, Si, alpha_i, TL )  10*log10(  1  +  (Sw*alpha_w  +  Si*alpha_i)./(Sw + Si)*10^(TL/10)  );



%% Find Values of TL and Aborption that will Meet the Target Insertion Loss - Ground Reflecting

% Assumption(s):
%
%   1.)  The ground is a hard reflecting survice
%   2.)  The enclosure is a cube.
%   3.)  There is no noise transmission through the ground.

enclosure.dimension = 2;  % m
    enclosure.area = 6 * enclosure.dimension^2;  % 20 m^2


% https://www.controlnoise.com/wp-content/uploads/2022/02/Acoustic-Enclosures-Datasheet.pdf
% https://www.cecoenviro.com/wp-content/uploads/2023/12/Acoustic-Enclosures-8pp-A4-web.pdf
% https://www.controlnoise.com/product/acoustic-enclosures/


switch ( 3 )

    case 1

        % 250 Hz - QBV-2
        alpha_w = 0.27;  % From specification sheet.
        TL = 20;  % From specification sheet.
            IL_estimates(1) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.absorption, TL );

        % 500 Hz - QBV-2
        alpha_w = 0.96;  % From specification sheet.
        TL = 29;  % From specification sheet.
            IL_estimates(2) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.absorption, TL );

        % 1 kHz - QBV-2
        % alpha_w = 1.13;  % From specification sheet.
        alpha_w = 0.99;  % From specification sheet.  See comment on slide 28 of Lecture 10.
        TL = 40;  % From specification sheet.
            IL_estimates(3) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.absorption, TL );

        % 2 kHz - QBV-2
        % alpha_w = 1.08;  % From specification sheet.
        alpha_w = 0.99;  % From specification sheet.  See comment on slide 28 of Lecture 10.
        TL = 50;  % From specification sheet.
            IL_estimates(4) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.absorption, TL );

        % 4 kHz - QBV-2
        alpha_w = 0.99;  % From specification sheet.
        TL = 55;  % From specification sheet.
            IL_estimates(5) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.absorption, TL );


    case 2

        % Note:  Abosrption values are carried over from QBV-2.

        % 250 Hz - QBV-3
        alpha_w = 0.27;  % From specification sheet.
        TL = 25;  % From specification sheet.
            IL_estimates(1) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.absorption, TL );

        % 500 Hz - QBV-2
        alpha_w = 0.96;  % From specification sheet.
        TL = 33;  % From specification sheet.
            IL_estimates(2) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.absorption, TL );

        % 1 kHz - QBV-2
```

```
144         % alpha_w = 1.13;  % From specification sheet.
145         alpha_w = 0.99;  % From specification sheet.  See comment on slide 28 of Lecture 10.
146         TL = 46;  % From specification sheet.
147             IL_estimates(3) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.
                    absorption, TL );
148
149         % 2 kHz - QBV-2
150         % alpha_w = 1.08;  % From specification sheet.
151         alpha_w = 0.99;  % From specification sheet.  See comment on slide 28 of Lecture 10.
152         TL = 53;  % From specification sheet.
153             IL_estimates(4) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.
                    absorption, TL );
154
155         % 4 kHz - QBV-2
156         alpha_w = 0.99;  % From specification sheet.
157         TL = 58;  % From specification sheet.
158             IL_estimates(5) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.
                    absorption, TL );
159
160
161     case 3
162
163         % Note:  Abosrption values are carried over from QBV-2.
164
165         % 250 Hz - QBV-3
166         alpha_w = 0.99;  % From specification sheet.
167         TL = 39;  % From specification sheet.
168             IL_estimates(1) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.
                    absorption, TL );
169
170         % 500 Hz - QBV-2
171         alpha_w = 0.96;  % From specification sheet.
172         TL = 59;  % From specification sheet.
173             IL_estimates(2) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.
                    absorption, TL );
174
175         % 1 kHz - QBV-2
176         % alpha_w = 1.13;  % From specification sheet.
177         alpha_w = 0.99;  % From specification sheet.  See comment on slide 28 of Lecture 10.
178         TL = 68;  % From specification sheet.
179             IL_estimates(3) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.
                    absorption, TL );
180
181         % 2 kHz - QBV-2
182         % alpha_w = 1.08;  % From specification sheet.
183         alpha_w = 0.99;  % From specification sheet.  See comment on slide 28 of Lecture 10.
184         TL = 67;  % From specification sheet.
185             IL_estimates(4) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.
                    absorption, TL );
186
187         % 4 kHz - QBV-2
188         alpha_w = 0.91;  % From specification sheet.
189         TL = 72;  % From specification sheet.
190             IL_estimates(5) = h_IL_large( enclosure.area, alpha_w, machine.area, machine.
                    absorption, TL );
191
192 end
193
194
195 [ octave_band_IL    IL_estimates.'    (octave_band_IL - IL_estimates.') ]
196
197
198 % What is the most restrictive case?
199
200
201 %% Find Values of TL and Aborption that will Meet the Target Insertion Loss - Ground with Cover
202
203 % Assumption(s):
204 %
205 %   1.)  The ground is covered with the absorption material.
206 %   2.)  The enclosure is a cube.
207
208
209
210 %% Clean-up
211
212 if ( ~isempty( findobj( 'Type', 'figure' ) ) )
213
```

```
    monitors = get( 0, 'MonitorPositions' );
        if ( size( monitors, 1 ) == 1 )
            autoArrangeFigures( 2, 2, 1 );
        elseif ( 1 < size( monitors, 1 ) )
            autoArrangeFigures( 2, 2, 1 );
        end
end


fprintf( 1, '\n\n\n*** Processing Complete ***\n\n\n' );



%% Reference(s)
```

6 Appendix - Matlab Code for Problem 6

```
1
2
3
4  %% Synopsis
5
6  % Lecture 11, Wednesday, February 19, 2025
7
8  % The compressor elevated above the ground.
9
10
11
12 %% Environment
13
14 close all; clear; clc;
15 % restoredefaultpath;
16
17 % addpath( genpath( '' ), '-begin' );
18 addpath( genpath( '../40 Assignments/00 Support' ), '-begin' );
19
20 % set( 0, 'DefaultFigurePosition', [  400  400  900  400  ] ); % [ left bottom width height ]
21 set( 0, 'DefaultFigurePaperPositionMode', 'manual' );
22 set( 0, 'DefaultFigureWindowStyle', 'normal' );
23 set( 0, 'DefaultLineLineWidth', 0.8 );
24 set( 0, 'DefaultTextInterpreter', 'Latex' );
25
26 format ShortG;
27
28 pause( 1 );
29
30 PRINT_FIGURES = 0;
31
32
33
34 %% Define Anonymous Functions
35
36 h_RA_term_1 = @( rho0, c , S, k, delta_mu, D, w )  ( rho0*c/S )  *  ( (k * sqrt( (2*3.178e-5) / (
       rho0*w) ) * D * 0.004 ) / (2*S) *1.4364 );
37 h_RA_term_2 = @( rho0, c , S, k, delta_mu, D, w, h )  ( rho0*c/S )  *  0.288*k*3.178e-5*log10((4*
       S)/(pi*h^2));
38 h_RA_term_3 = @( rho0, c , S, k, delta_mu, D, w, h )  ( rho0*c/S )  *  (0.5*S*k^2)/(2*pi);
39
40
41
42 %% Define Compressor
43
44 compressor.width = 1;  % m
45 compressor.depth = 1;  % m
46 compressor.height = 2;  % m
47     compressor.area = 2*(compressor.width * compressor.depth) + 2*(compressor.width * compressor.
           height) + 2*(compressor.depth * compressor.height);  % 3 m^2
48     compressor.volume = compressor.width * compressor.depth * compressor.height;  % m^3
49
50 compressor.power_level = 105;  % dB re: 1e-12 Watts
51 compressor.frequency = 50;  % Hz
52
53 c = 343;  % m/s
54
55 rho0 = 1.2;  % kg/m^3  CHECK
56
57
58
59 %% Sound Level Target
60
61 sound_level_target = 82;  % dB re: 20e-6 Pascals
62
63
64
65 %% Define Workshop
66
67 R = 40;  % m^2 or Sabins
68
69
70
71 %% Define Close-fitting Enclosure
72
```

```
73 helmholtz_factor = (2 * pi * compressor.frequency) / c;  % 0.92 m
74 %
75 %  For a small enclosure, k*d << 1.  Therefore d << 1.1.
76 d = 0.75;
77 d = 0.25;
78 % d = 1;
79     % helmholtz_factor * d;  % 0.69
80
81 enclosure.width = compressor.width + d;  % m
82 enclosure.depth = compressor.depth + d;  % m
83 enclosure.height = 3;  % m;  compression height is 2 m
84 % enclosure.height = compressor.height + d;
85     enclosure.area = 2*(enclosure.width * enclosure.depth) + 2*(enclosure.width * enclosure.
       height) + 2*(enclosure.depth * enclosure.height);
86     enclosure.volume = enclosure.width * enclosure.depth * enclosure.height;
87
88 enclosure.E = 3.6e9;  % Pascals
89 enclosure.thickness = 3.81e-2;  % m
90 enclosure.density = 800;  % kg/m^3
91 enclosure.poisson_ratio = 0.25;  % Unitless
92
93 % Clamped boundary conditions.
94
95
96
97 %% Calculate Diffuse Sound Pressure Level
98
99 % Assume distance is beyond the critical distance, so the distance value is
100 % large and its associated term is not relevant.
101
102 sound_pressure_level = 105  +  10*log10( 4/R );  % 95 dB SPL
103
104
105
106 %% Calculate the Required Insertion Loss
107
108 target_insertion_loss = sound_pressure_level - 82  % 13 dB
109
110
111
112 %% Insertion Loss
113
114 % For the insertion loss to be high, we need:
115 %
116 %   1.)  Compliance of the air to be high;  volume of enclosure must be large.
117 %   2.)  Compliance of each enclosure wall to be low;  low area, high stiffness, edges clamped).
118 %           AREA IS THE DOMINATE FACTOR OVER VOLUME.
119
120
121 % The correction factor for clamped walls.  See Figure 12.4 on slide 9 of the Lecture 11 notes.
122 aspect_ratio = enclosure.height / enclosure.width;  % 1.7
123     correction_factor = 2;  % Approximate value read from the Figure 12.4.
124
125 bending_stiffness = ( enclosure.E * enclosure.thickness^3 ) / ( 12*( 1 - enclosure.poisson_ratio
        ^2 ) );  % 1.78e7
126     h_wall_compliance = @( wall_area, correction_factor )  ( 0.001 * wall_area^3 *
          correction_factor ) / bending_stiffness;
127
128 Ca = enclosure.volume / ( rho0 * c^2 );
129
130
131 % Top
132 top.area = enclosure.width * enclosure.depth;
133 top.aspect_ratio = max( enclosure.width, enclosure.depth ) / min( enclosure.width, enclosure.
       depth );
134 top.correction_factor = 3.8;
135     top.compliance = h_wall_compliance( top.area, top.correction_factor );
136
137
138 % Side 1
139 side_1.area = enclosure.depth * enclosure.height;
140 side_1.aspect_ratio = max( enclosure.width, enclosure.height ) / min( enclosure.width, enclosure.
       height );
141 side_1.correction_factor = 2;
142     side_1.compliance = h_wall_compliance( side_1.area, side_1.correction_factor );
143
144 % Side 2
145 side_2.compliance = side_1.compliance;
```

```
146
147
148 % Side 3
149 side_3.area = enclosure.width * enclosure.height;
150 side_3.aspect_ratio = max( enclosure.width, enclosure.height ) / min( enclosure.width, enclosure.
    height );
151 side_3.correction_factor = 2;
152     side_3.compliance = h_wall_compliance( side_3.area, side_3.correction_factor );
153
154 % Side 4
155 side_4.compliance = side_3.compliance;
156
157
158 estimated_insertion_loss = 20*log10( 1 + Ca / ( top.compliance + 2*side_1.compliance + 2* side_3.
    compliance ) );  % 59.2 dB
159
160
161
162 %% Compliance of the Air Intake
163
164 air_intake_radius = 10e-2;  % m
165 air_intake_thickness = enclosure.thickness;  % m
166 air_intake_frequency = 50;  % Hz
167     air_intake_angular_frequency = 2*pi*air_intake_frequency;  % radians/s
168
169 viscosity = 1.5e-5;  % m^2/s
170
171 h = 0.3;  % CHECK
172
173 f = 50;
174     term_1 = h_RA_term_1( rho0, c, pi*(air_intake_radius*2)^2/4, 2*pi*f/c, sqrt( (2 * 3.178e-5 )
        / ( 2*pi*f * rho0 ) ), pi * 0.1, 2*pi*f );
175     term_2 = h_RA_term_2( rho0, c, pi*(air_intake_radius*2)^2/4, 2*pi*f/c, sqrt( (2 * 3.178e-5 )
        / ( 2*pi*f * rho0 ) ), pi * 0.1, 2*pi*f, 0.3 );
176     term_3 = h_RA_term_3( rho0, c, pi*(0.1)^2/4, 2*pi*f/c, sqrt( (2 * 3.178e-5 ) / ( 2*pi*f *
        rho0 ) ), pi * 0.1, 2*pi*f, 0.3 );
177         impedance.real = term_1 + term_2 + term_3;
178
179
180 % Deng (1998)
181 epsilon = 1;
182     L_o = air_intake_radius * ( 1.27 / (1 + 1.92*epsilon) - 0.086 );
183
184 L_e =  enclosure.thickness + 2*L_o;
185     impedance.imaginary = 1j * rho0 * (2 * pi * f) * L_e / ( pi*0.1^2/4 );
186
187
188 impedance.net = impedance.real + impedance.imaginary;
189     compliance_of_hole = 1 / impedance.net;
190         Cl = abs( compliance_of_hole );
191
192 estimated_insertion_loss
193 estimated_insertion_loss_with_hole = 20*log10( (Cl + Ca)  / ( Cl + ( top.compliance + 2*side_1.
    compliance + 2* side_3.compliance ) ) )
194
195
196 13 - estimated_insertion_loss_with_hole;
197
198
199
200 critical_frequency = c^2/(2*pi)*sqrt( enclosure.density * enclosure.thickness / bending_stiffness
    );
201 %
202 % The critical frequency is 25 Hz.
203 %
204 % The frequency of the compressor is 50 Hz.
205
206
207
208
209
210 %% Clean-up
211
212 if ( ~isempty( findobj( 'Type', 'figure' ) ) )
213     monitors = get( 0, 'MonitorPositions' );
214         if ( size( monitors, 1 ) == 1 )
215             autoArrangeFigures( 2, 2, 1 );
216         elseif ( 1 < size( monitors, 1 ) )
```

```
217                 autoArrangeFigures( 2, 2, 1 );
218             end
219 end
220
221
222 fprintf( 1, '\n\n\n*** Processing Complete ***\n\n\n' );
223
224
225
226 %% Reference(s)
```