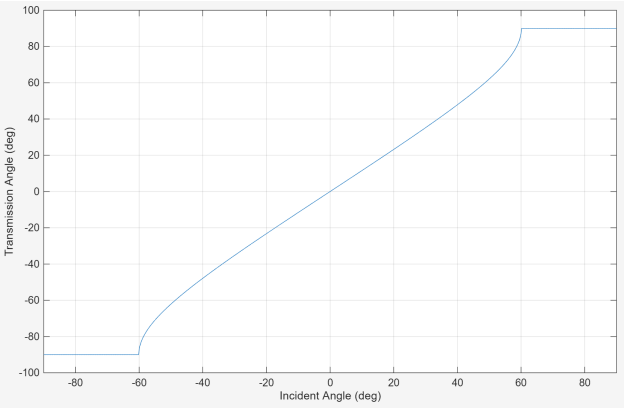
MECH6066 HW#5

Slade Brooks
M13801712

11.17.25

Problem 1

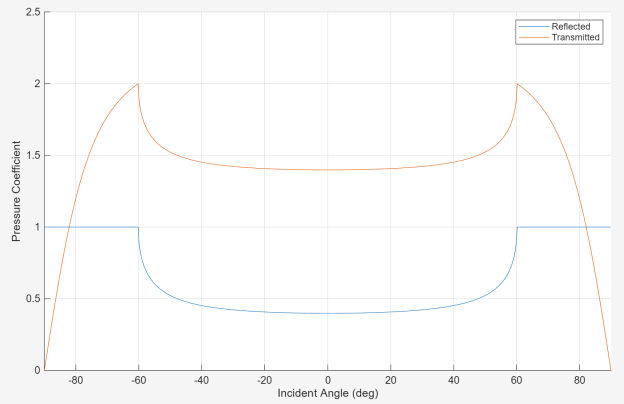
(a)



(b)

From the plot, it appears the critical angle is 60°. We can verify this analytically from: $\sin\theta_c = \frac{c_1}{c_2}$. We will do this in matlab to determine the critical angle and we get that $\boxed{\theta_c = 61.12^\circ}$.

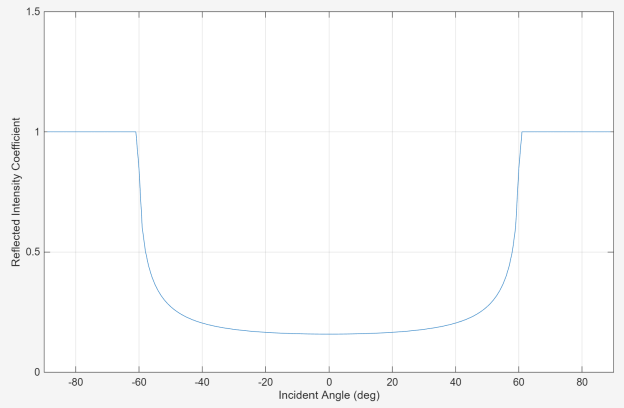
(c)



(d)

At normal incidence ($\theta_i = 0°$), $\boxed{\bar{R} = 0.398 \text{ and } \bar{T} = 1.398}$.

(e)



(f)

We can determine the Brewster angle based on the plot in part e. The brewster angle will be at 100% transmission, so our reflected intensity coefficient would be 0. We can see that since this does not happen, there is no brewster angle for this combination of materials.

Problem 2

(a)

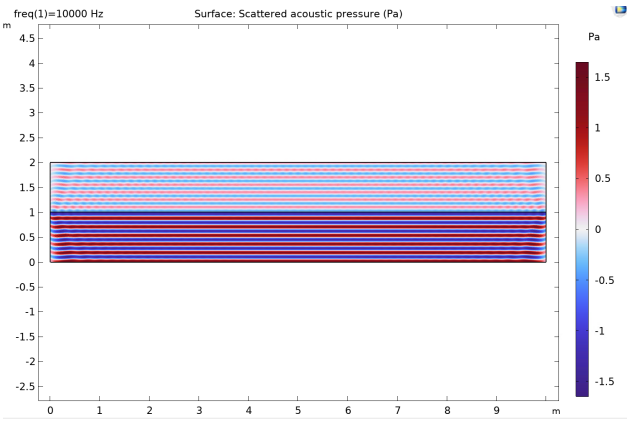
See attached model.

(b)

Yes, there are downwards moving waves and a standing wave in the water. The transmitted wave is roughly 1.4 Pa, so it matches very closely to previous calculations.

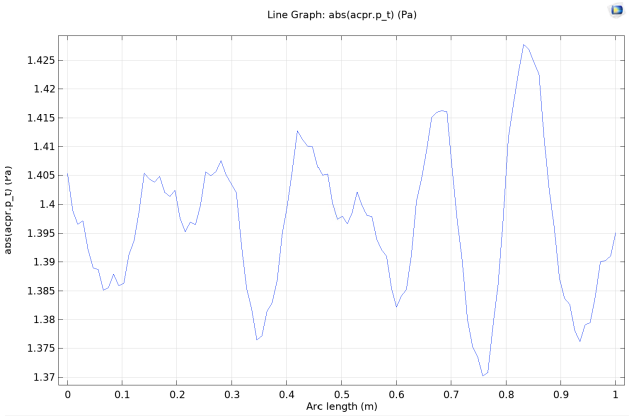
(c)

When plotting just ps, we can see that the reflected wave is rougly 0.4 Pa in amplitude which is exactly what we calculated previously.



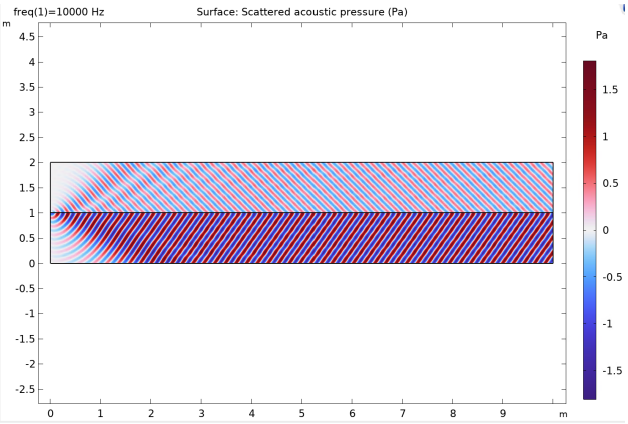
(d)

We can see that the amplitude does not vary since there is just a wave transmitted into the sand and no standing wave to change the amplitude.

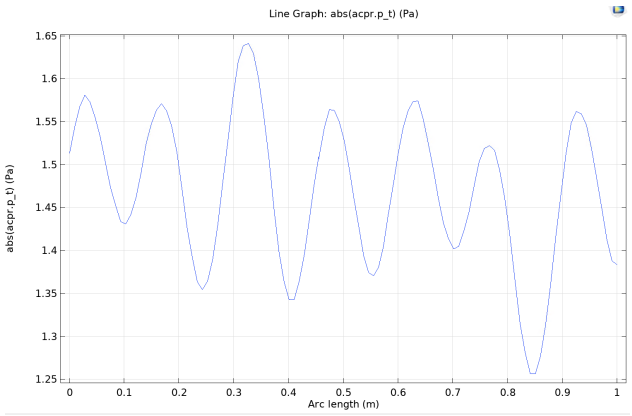


(e)

We can see that the reflected pressure does match what is expected (roughly 0.5 Pa).

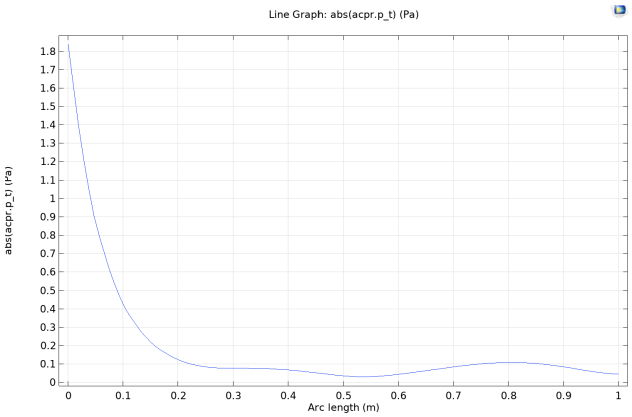


We can see that the amplitude still does not vary vertically, and shouldn't because it is still just transmitted pressure into the quartz sand not a standing wave.



(f)

The waves in the sand move only in the x direction. I believe these would be transverse waves. The amplitude does vary in the vertical direction but I believe this is due to artifacts in the simulation, not a physical phenomenon.



Problem 3

(a)

See attached model.

(b)

The generated waves can be approximated as spherical. The wavelength of the generated sound will be 0.343 meters and the largest dimension of the speaker geometry is only 0.02 meters, which should be small enough compared to the wavelength to approximate the generated wave as spherical.

(c)

Evaluating at the far right side of the domain gave an amplitude of 0.007 Pa at 1 m, which means $\boxed{A = 0.007 \text{ Pa·m}}$

(d)

$$I = re\{0.5 \cdot p \cdot u^*\}$$

$$I = re\{\frac{p}{2}\left[\frac{1}{Z_0}\left(1 + \frac{1}{jkr}\right)p\hat{r}\right]^*\}$$

The exponential terms will now cancel out since one is a conjugate, and because we are taking only the real any remaining j terms disappear.

$$I = \frac{|A|}{2r}e^{j(\omega t - kr)}\frac{1}{Z_0}\frac{|A|}{r}e^{-j(\omega t - kr)}\hat{r}$$

$$I = \frac{|A|}{2r}\frac{1}{Z_0}\frac{|A|}{r}\hat{r}$$

$$\boxed{I = \frac{|A|^2}{2Z_0 r^2}\hat{r}}$$

We can see that the intensity goes down relative to the radius squared as we move farther away.

(e)

$$I = \frac{|A|^2}{2Z_0 r^2} = \frac{0.007^2}{2(343 \cdot 1.15)} = 6.2e-8 W/m^2$$

$$SIL = 10\log_{10}(I/I_{ref}) = 10\log_{10}(6.2e-8/10^{-12}) = \boxed{SIL = 48dB}$$

I get an SPL of just under 48 dB from the comsol model, so the approximation is very accurate.

(f)

$$W = I4\pi a^2 = \frac{|A|^2}{2Z_0 r^2} 4\pi a^2 = \frac{2\pi |A|^2}{Z_0} = \boxed{7.8e-7W}$$

The power does not depend on the distance. The intensity depends on the distance, but the power equation simplifies to not have any radius term in it, so it depends only on the amplitude of the pressure and the impedance.

(g)

The comsol model reports a power of $8.3e-7$ W, whereas I calculated a power of $7.8e-7$ W. These values do differ slighlty, but are fairly close. I believe the difference in value comes from the spherical assumption. The spherical assumption for the analytical value assumes a spherical source at 0, 0. Our comsol model is slightly offset from that and has a linear moving source instead of a single breathing point, so it makes sense that comsol would calculate a higher power. At some points, the sound generating surface is closer to the edge of the domain than it would be for the spherical approximation, and the pressure wave generated is larger since it has some length to it.

(h)

I would not assume the waves are spherical. The wavelength would go down to 0.03 m, which is only slightly bigger than the radius of the speaker, so it is probably not a large enough difference to be considered spherical.

Problem 4

My only change for this assignment would be less comsol work. I think this assignment is well-structured and helpful for understanding some of the concepts. However, I sometimes have issues where comsol is a little clunky or confusing and I waste time troubleshooting comsol instead of getting valuable insights.

Problem 1 Matlab

```
clear variables; close all;
```

```
% define properties from appendix
rhoSW = 1026;
cSW = 1500;
ZSW = 1.54e6;
rhoQS = 2070;
cQS = 1730;
ZQS = 3.58e6;

%% Part A
% set range of angles to check
thetai = -90:1:90;

% calculate xmission angle for each
thetat = asind(cQS/cSW.*sind(thetai));

% plot results
figure
plot(thetai, thetat)
xlim([thetai(1) thetai(end)]); xlabel("Incident Angle (deg)")
ylim([-100 100]); ylabel("Transmission Angle (deg)")
grid on

%% Part B
% calc critical angle
thetac = asind(cSW/cQS);

%% Part C
% calc reflection coef (magnitude)
Rbar = abs((ZQS./cosd(thetat) - ZSW./cosd(thetai))./(ZQS./cosd(thetat) + ZSW./cosd(theta

% calc xmission coef (magnitude)
Tbar = abs(2*(ZQS./cosd(thetat))./(ZQS./cosd(thetat) + ZSW./cosd(thetai)));

% plot results
figure
hold on
plot(thetai, Rbar); plot(thetai, Tbar)
hold off
```

```
xlim([thetai(1) thetai(end)]); xlabel("Incident Angle (deg)")
ylim([0 2.5]); ylabel("Pressure Coefficient")
legend(["Reflected", "Transmitted"])
grid on

%% Part D
% calculate reflection intensity coeff
RI = Rbar.^2;

% plot
figure
plot(thetai, RI)
xlim([thetai(1) thetai(end)]); xlabel("Incident Angle (deg)")
ylim([0 1.5]); ylabel("Reflected Intensity Coefficient")
grid on
```

Hw5.2

Report date	Nov 17, 2025, 8:58:57 PM

Contents

1 Global Definitions

Date	Nov 16, 2025, 12:10:32 PM

GLOBAL SETTINGS

Name	Hw5.2.mph
Path	\\clusterfsnew.ceas1.uc.edu\students\brooksl\desktop\hw5.2.mph
Version	COMSOL Multiphysics 6.3 (Build: 420)

USED PRODUCTS

Acoustics Module
COMSOL Multiphysics

COMPUTER INFORMATION

CPU	Intel64 Family 6 Model 198 Stepping 2, 28 cores, 63.46 GB RAM
Operating system	Windows 11

1.1 PARAMETERS

PARAMETERS 1

Name	Expression	Value	Description
length	10[m]	10 m	
height	1[m]	1 m	
rho1	1026[kg/m^3]	1026 kg/m³	
c1	1500[m/s]	1500 m/s	
rho2	2070[kg/m^3]	2070 kg/m³	
c2	1730[m/s]	1730 m/s	
p_input	1[Pa]	1 Pa	
theta_i	70[deg]	1.2217 rad	
f_study	10[kHz]	10000 Hz	

1.2 SHARED PROPERTIES

1.2.1 Default Model Inputs

Tag	cminpt

2 Component 1

SETTINGS

Description	Value
Unit system	Same as global system (SI)

2.1 DEFINITIONS

2.1.1 Coordinate Systems

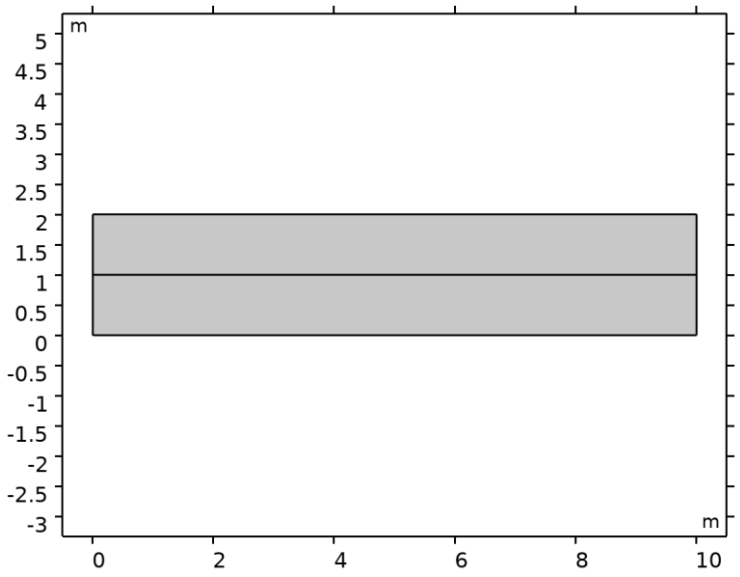
Boundary System 1

Coordinate system type	Boundary system
Tag	sys1

COORDINATE NAMES

First	Second	Third
t1	n	to

2.2 GEOMETRY 1



Geometry 1

UNITS

Length unit	m
Angular unit	deg

GEOMETRY STATISTICS

Description	Value

Description	Value
Space dimension	2
Number of domains	2
Number of boundaries	7
Number of vertices	6

2.2.1 Rectangle 1 (r1)

SIZE AND SHAPE

Description	Value
Width	length
Height	height

POSITION

Description	Value
Position	{0, 0}

2.2.2 Rectangle 2 (r2)

SIZE AND SHAPE

Description	Value
Width	length
Height	height

POSITION

Description	Value
Position	{0, height}

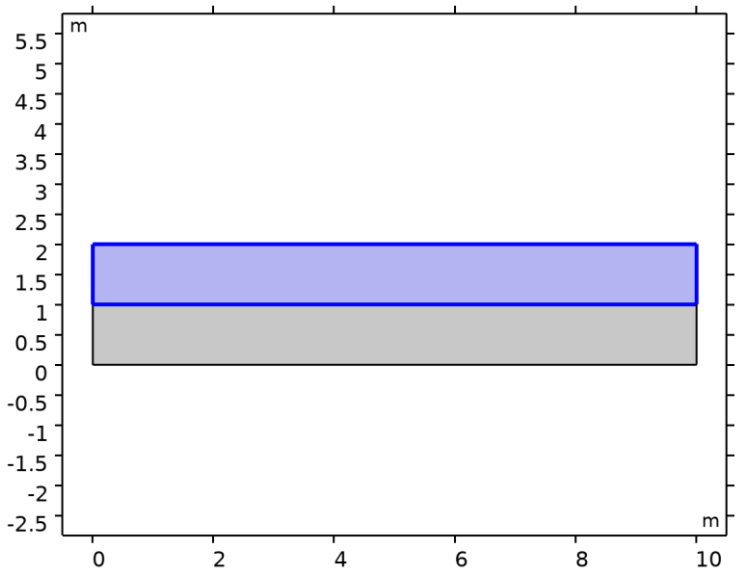
2.2.3 Form Union (fin)

INFORMATION

Description	Value
Build message	Formed union of 2 solid objects. Union has 2 domains, 7 boundaries, and 6 vertices.

2.3 MATERIALS

2.3.1 seawater



seawater

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

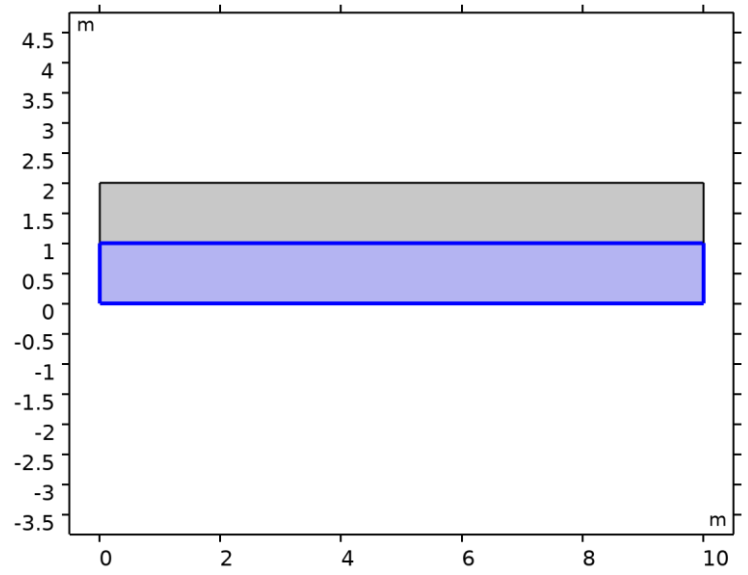
MATERIAL PARAMETERS

Name	Value	Unit	Property group
Density	rho1	kg/m³	Basic
Speed of sound	c1	m/s	Basic

BASIC

Description	Value	Unit
Density	rho1	kg/m³
Speed of sound	c1	m/s

2.3.2 quartz sand



quartz sand

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: Domain 1

MATERIAL PARAMETERS

Name	Value	Unit	Property group
Density	rho2	kg/m³	Basic
Speed of sound	c2	m/s	Basic

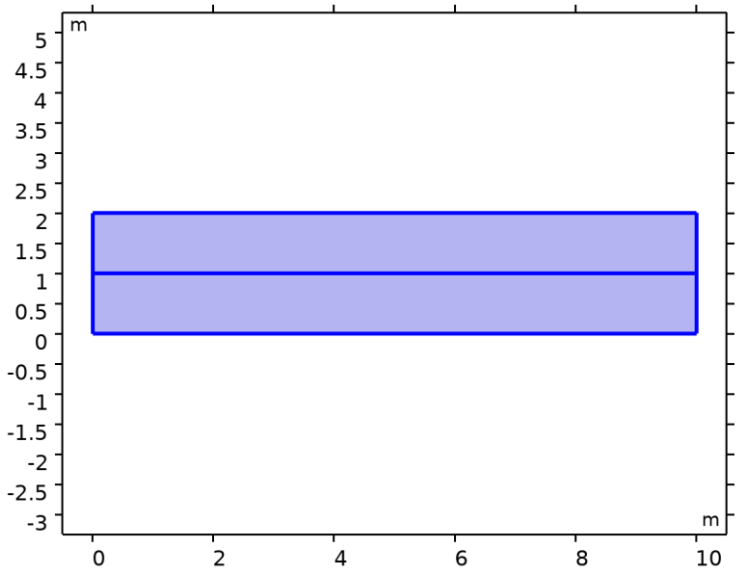
BASIC

Description	Value	Unit
Density	rho2	kg/m³
Speed of sound	c2	m/s

2.4 PRESSURE ACOUSTICS, FREQUENCY DOMAIN

USED PRODUCTS

Acoustics Module
COMSOL Multiphysics



Pressure Acoustics, Frequency Domain

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

EQUATIONS

$$\nabla \cdot \left(-\frac{1}{\rho_c}(\nabla p_t - \mathbf{q}_d)\right) - \frac{k_{eq}^2 p_t}{\rho_c} = Q_m$$

$$p_t = p + p_b$$

$$k_{eq}^2 = \left(\frac{\omega}{c_c}\right)^2 - k_z^2$$

2.4.1 Interface Settings

Physics Symbols

SETTINGS

Description	Value
Enable physics symbols	On

Discretization

SETTINGS

Description	Value
Element order	Quadratic Lagrange

Physics-Controlled Mesh

SETTINGS

Description	Value
Maximum mesh element size control parameter	From study
Number of mesh elements per wavelength	Automatic

Pressure Acoustics Equation Settings

SETTINGS

Description	Value	Unit
Out-of-plane wave number	0	rad/m

Global Port Settings

SETTINGS

Description	Value
Port sweep settings	No port sweep
Mode shape normalization	Amplitude normalization

Sound Pressure Level Settings

SETTINGS

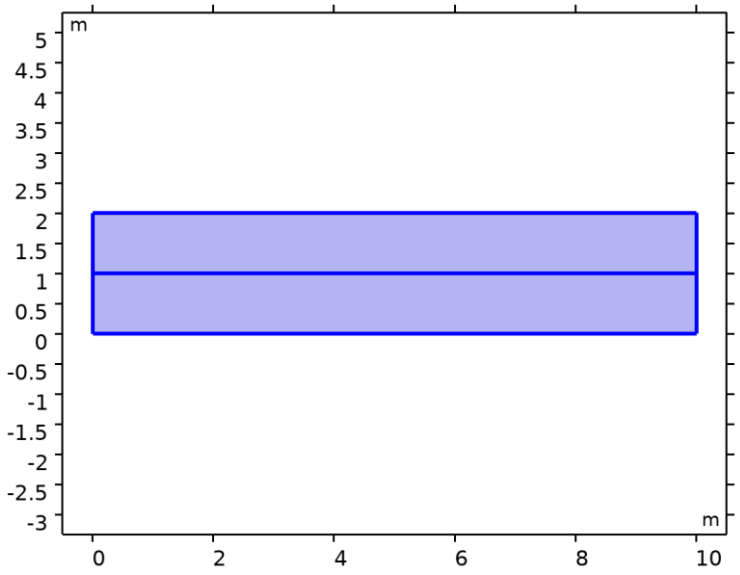
Description	Value
Reference pressure for the sound pressure level	Use reference pressure for air

Typical Wave Speed for Perfectly Matched Layers

SETTINGS

Description	Value	Unit
Typical wave speed for perfectly matched layers	real(acpr.c_c)	m/s

2.4.2 Pressure Acoustics 1



Pressure Acoustics 1

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

EQUATIONS

$$\nabla \cdot \left(-\frac{1}{\rho_c}\left(\nabla p_t - \mathbf{q}_d\right)\right) - \frac{k_{eq}^2 p_t}{\rho_c} = Q_m$$

$$p_t = p + p_b$$

$$k_{eq}^2 = \left(\frac{\omega}{c_c}\right)^2 - k_z^2$$

$$c_c = c, \quad \rho_c = \rho$$

Pressure Acoustics Model

SETTINGS

Description	Value
Fluid model	Linear elastic
Specify	Density and speed of sound
Speed of sound	From material
Density	From material

Model Input

SETTINGS

Description	Value
Temperature	Common model input
Absolute pressure	Common model input

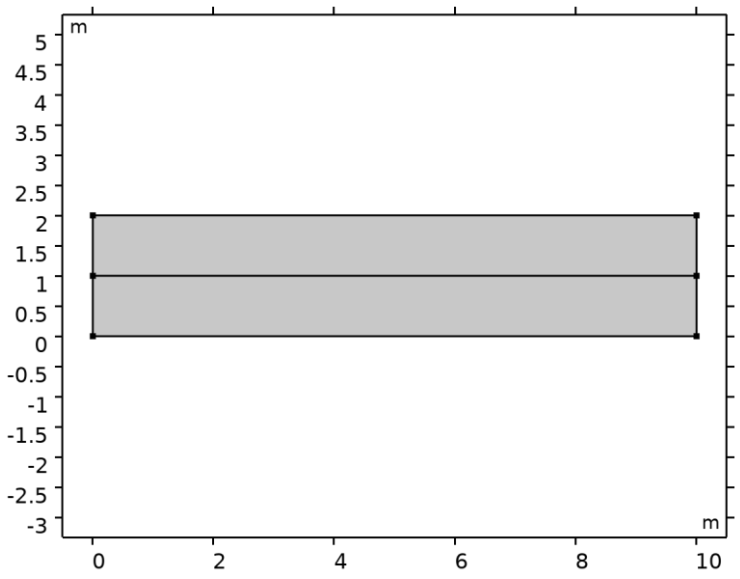
USED PRODUCTS

COMSOL Multiphysics

PROPERTIES FROM MATERIAL

Property	Material	Property group
Density	seawater	Basic
Speed of sound	seawater	Basic
Density	quartz sand	Basic
Speed of sound	quartz sand	Basic

2.4.3 Sound Hard Boundary (Wall) 1



Sound Hard Boundary (Wall) 1

SELECTION

Geometric entity level	Boundary
Selection	Geometry geom1: Dimension 1: All boundaries

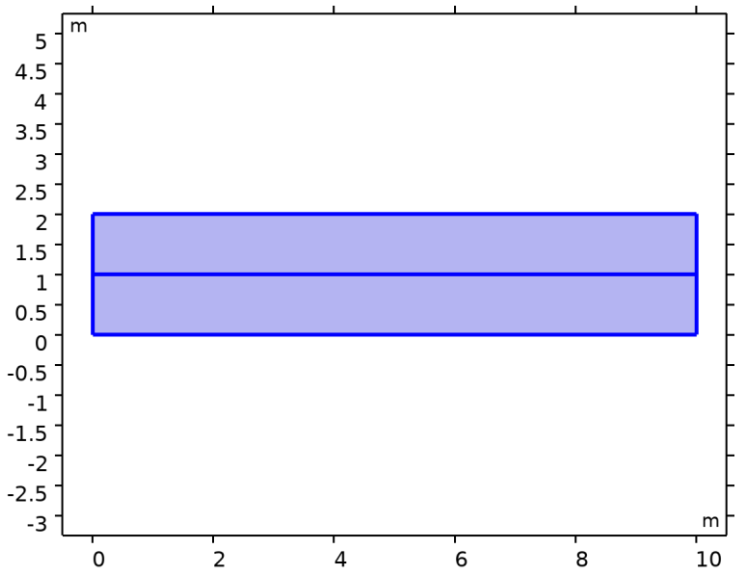
EQUATIONS

$$-\mathbf{n}\cdot\left(-\frac{1}{\rho_c}(\nabla p_t-\mathbf{q}_d)\right)=0$$

USED PRODUCTS

COMSOL Multiphysics

2.4.4 Initial Values 1



Initial Values 1

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

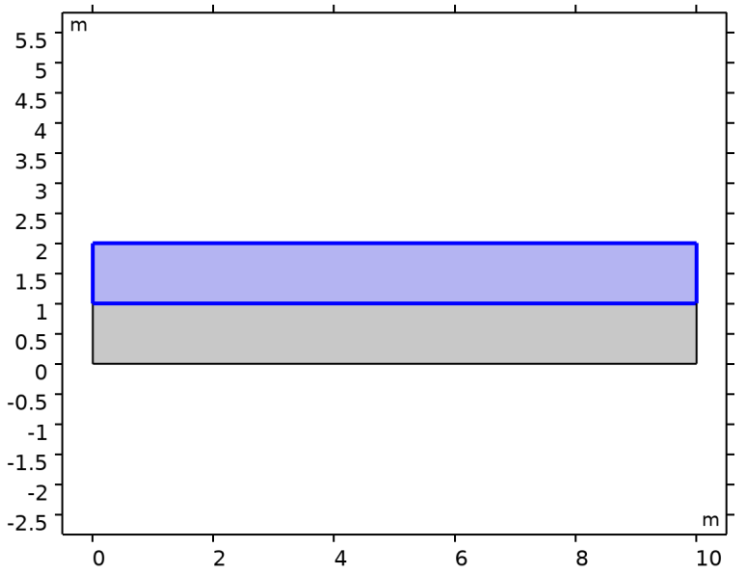
SETTINGS

Description	Value	Unit
Acoustic pressure	0	Pa

USED PRODUCTS

COMSOL Multiphysics

2.4.5 Background Pressure Field 1



Background Pressure Field 1

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: Domain 2

EQUATIONS

$$\nabla \cdot \left(-\frac{1}{\rho_c}(\nabla p_t - \mathbf{q}_d)\right) - \frac{k_{eq}^2 p_t}{\rho_c} = Q_m$$

$$p_t = p + p_b$$

$$k_{eq}^2 = \left(\frac{\omega}{c_c}\right)^2 - k_z^2$$

$$p_b = p_0 e^{i\phi} e^{-ik_s \frac{(\mathbf{x}\cdot\mathbf{e}_k)}{|\mathbf{e}_k|}}$$

$$k_s^2 = \left(\frac{\omega}{c}\right)^2 - k_z^2$$

$$\mathbf{v}_b = -\frac{\nabla p_b}{i\omega\rho}$$

Background Pressure Field

SETTINGS

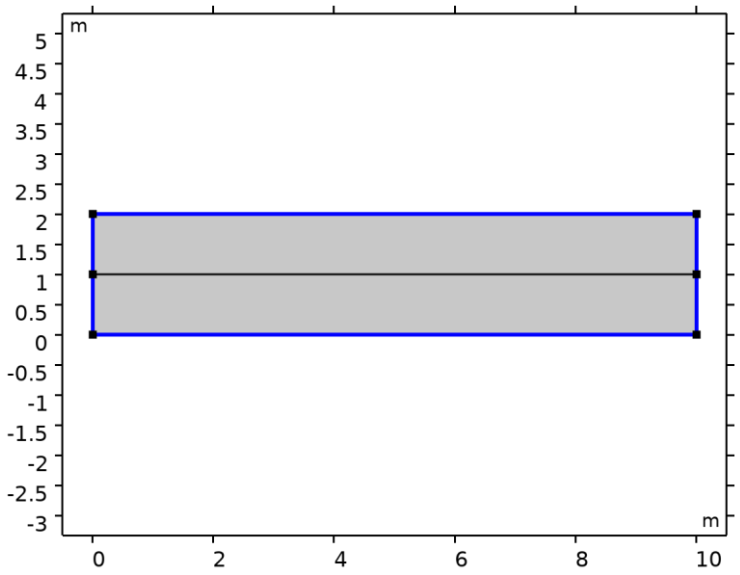
Description	Value	Unit
Pressure field type	Plane wave	
Pressure amplitude	p_input	Pa
Speed of sound	From material	

Description	Value	Unit
Wave direction, x-component	sin(theta_i)	
Wave direction, y-component	-cos(theta_i)	
Wave direction, z-component	0	
Phase	0	rad
Calculate background and scattered field intensity	On	
Density	From material	
Material	Domain material	

PROPERTIES FROM MATERIAL

Property	Material	Property group
Speed of sound	seawater	Basic
Density	seawater	Basic

2.4.6 Plane Wave Radiation 1



Plane Wave Radiation 1

SELECTION

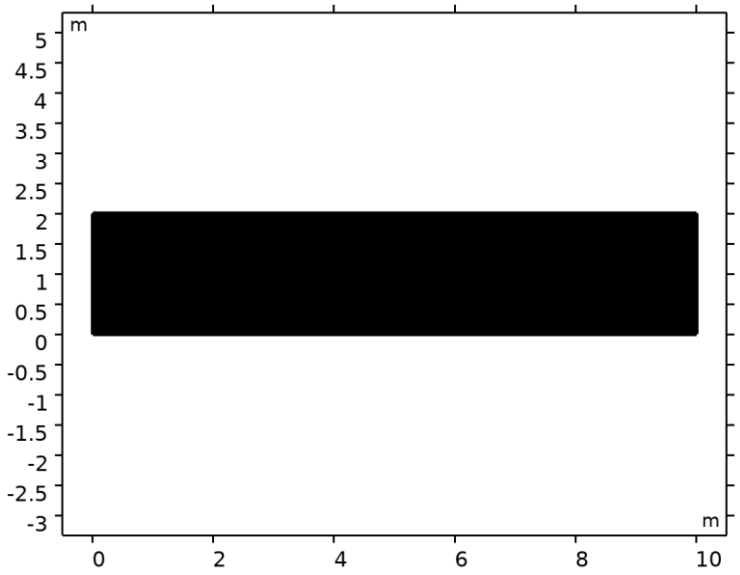
Geometric entity level	Boundary
Selection	Geometry geom1: Dimension 1: Boundaries 1–3, 5–7

EQUATIONS

$$-\mathbf{n}\cdot\left(-\frac{1}{\rho_c}(\nabla p_t-\mathbf{q}_d)\right)+i\frac{k_{eq}}{\rho_c}p+\frac{i}{2k_{eq}\rho_c}\Delta_{\parallel}p=Q_i$$

USED PRODUCTS

2.5 MESH 1



Mesh 1

2.5.1 Size (size)

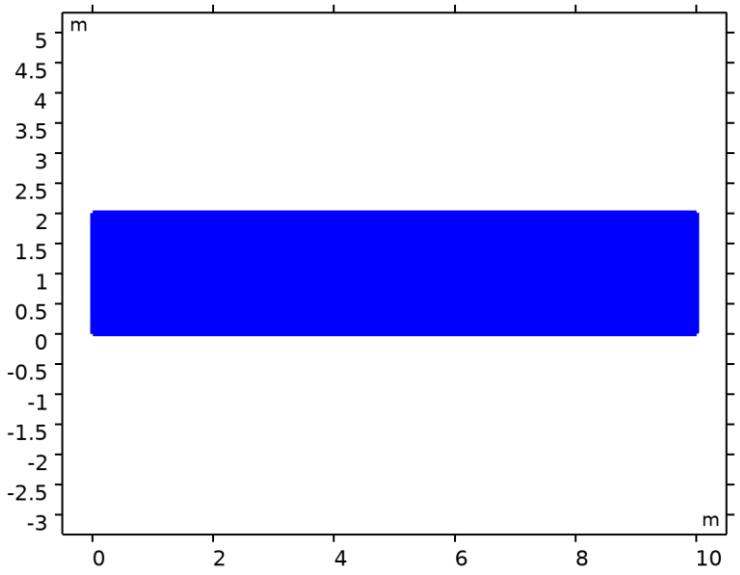
SETTINGS

Description	Value
Maximum element size	0.2
Minimum element size	1E-4
Curvature factor	0.25
Maximum element growth rate	1.2
Predefined size	Extra fine
Custom element size	Custom

2.5.2 Size Expression 1 (se1)

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: Domains 1–2



Size Expression 1

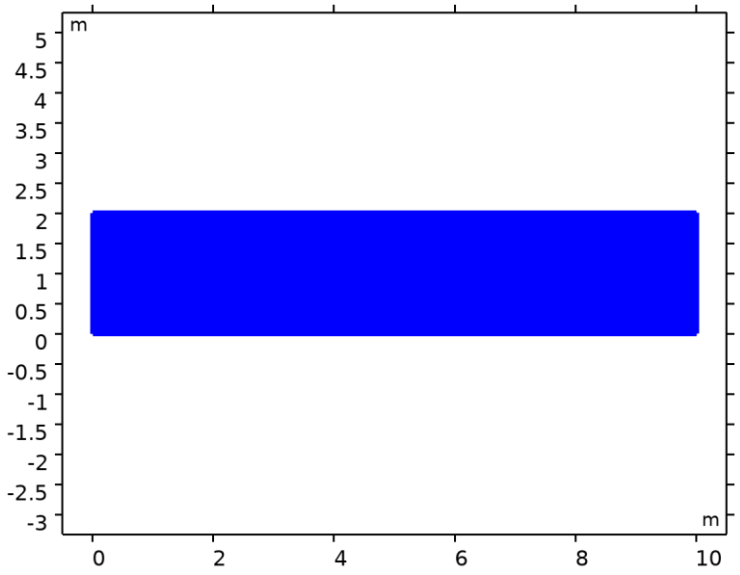
SETTINGS

Description	Value
Evaluate on	Initial expression
Study step	Study 1: Frequency Domain
Size expression	subst(real(acpr.c_c), acpr.freq, freqmax)/freqmax/5
Reevaluate with updated model	

2.5.3 Free Triangular 1 (ftri1)

SELECTION

Geometric entity level	Domain
Selection	Remaining



Free Triangular 1

SETTINGS

Description	Value
Number of iterations	4
Maximum element depth to process	4

INFORMATION

Description	Value
Last build time	< 1 second
Built with	COMSOL 6.3.0.420 (win64), Nov 17, 2025, 8:52:46 PM

3 Study 1

COMPUTATION INFORMATION

Computation time	1 s

3.1 FREQUENCY DOMAIN

Frequencies (Hz)
f_study

STUDY SETTINGS

Description	Value
Include geometric nonlinearity	Off

SETTINGS

Description	Value
Frequencies	10000

PHYSICS AND VARIABLES SELECTION

Key	Solve for
Pressure Acoustics, Frequency Domain (acpr)	On

STORE IN OUTPUT

Interface	Output	Selection
Pressure Acoustics, Frequency Domain (acpr)	Physics controlled	

MESH SELECTION

Component	Mesh
Component 1	Mesh 1

3.2 SOLVER CONFIGURATIONS

3.2.1 Solution 1

Compile Equations: Frequency Domain (st1)

STUDY AND STEP

Description	Value
Use study	Study 1
Use study step	Frequency Domain

Dependent Variables 1 (v1)

GENERAL

Description	Value
Defined by study step	Step 1: Frequency Domain

INITIAL VALUE CALCULATION CONSTANTS

Constant name	Initial-value source
freq	f_study

Acoustic Pressure (comp1.p) (comp1_p)

GENERAL

Description	Value
Field components	comp1.p

Stationary Solver 1 (s1)

GENERAL

Description	Value
Defined by study step	Step 1: Frequency Domain

RESULTS WHILE SOLVING

Description	Value
Probes	None

Advanced (aDef)

ASSEMBLY SETTINGS

Description	Value
Reuse sparsity pattern	On
Allow complex-valued output from functions with real input	On

Parametric 1 (p1)

GENERAL

Description	Value
Defined by study step	Step 1: Frequency Domain
Run continuation for	No parameter

PARAMETERS

Parameter name	Parameter value list	Parameter unit
freq	f_study	Hz

Fully Coupled 1 (fc1)

GENERAL

Description	Value

Description	Value
Linear solver	Direct

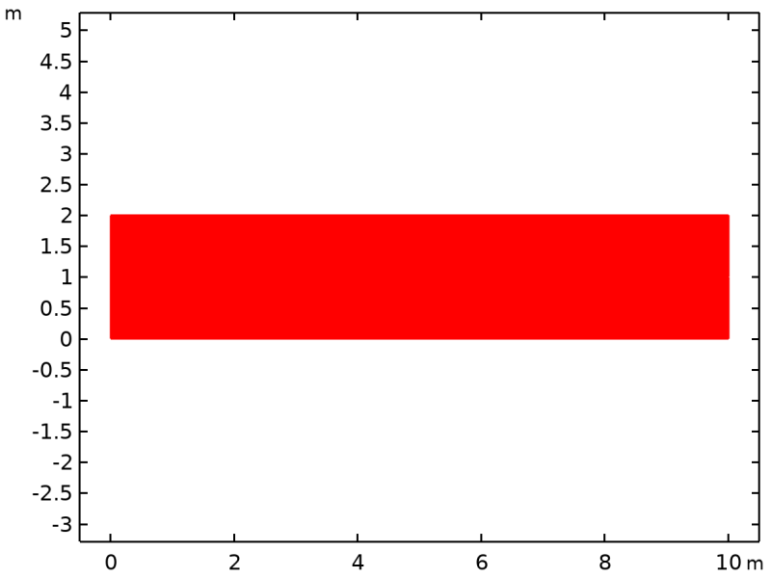
4 Results

4.1 DATASETS

4.1.1 Study 1/Solution 1

SOLUTION

Description	Value
Solution	Solution 1 (sol1)
Component	Component 1 (comp1)



Dataset: Study 1/Solution 1

4.1.2 Cut Line 2D 1

DATA

Description	Value
Dataset	Study 1/Solution 1 (sol1)

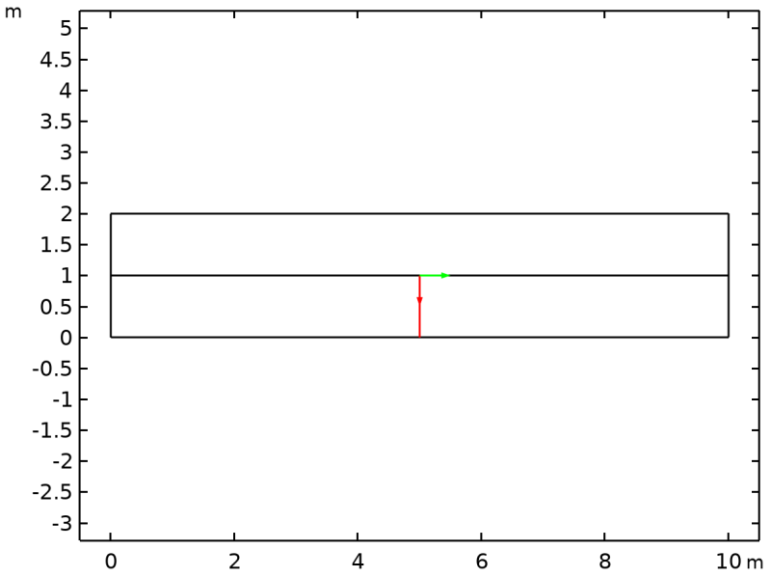
LINE DATA

Description	Value
Line entry method	Two points
Points	{{length/2, height}, {length/2, 0}}

ADVANCED

Description	Value
Space variable	cln1x

Description	Value
Normal variables	{cln1nx, cln1ny}
Tangent variables	{cln1tx, cln1ty}



Dataset: Cut Line 2D 1

4.1.3 Cut Line 2D 2

DATA

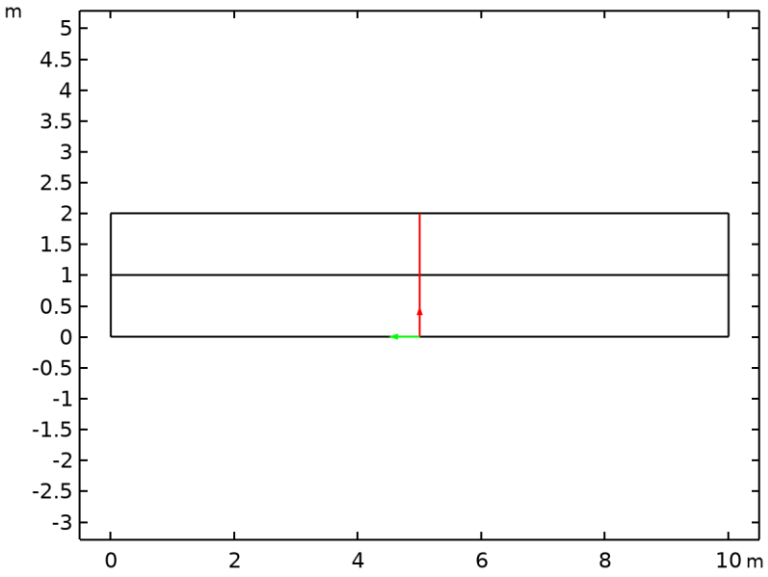
Description	Value
Dataset	Study 1/Solution 1 (sol1)

LINE DATA

Description	Value
Line entry method	Two points
Points	{{5, 0}, {5, 2}}

ADVANCED

Description	Value
Space variable	cln2x
Normal variables	{cln2nx, cln2ny}
Tangent variables	{cln2tx, cln2ty}



Dataset: Cut Line 2D 2

4.2 TABLES

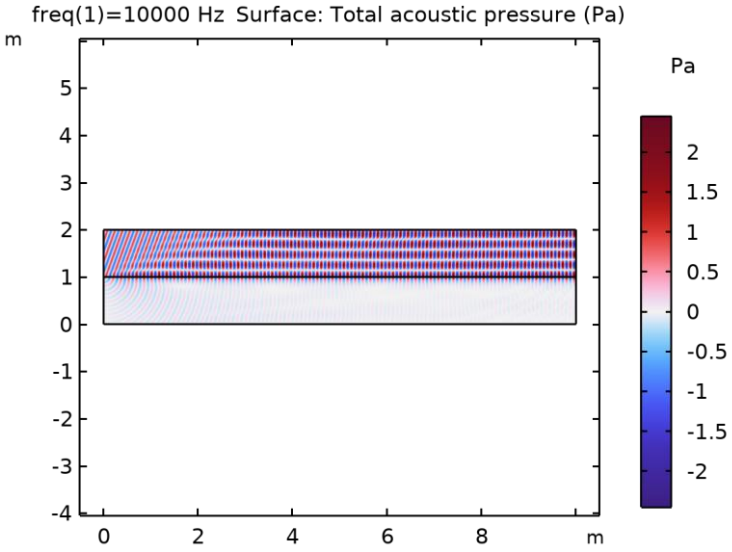
4.2.1 Evaluation 2D

Interactive 2D values

x	y	Value
4.9514	0.19459	-0.0025911
3.6091	0.26523	0.012694

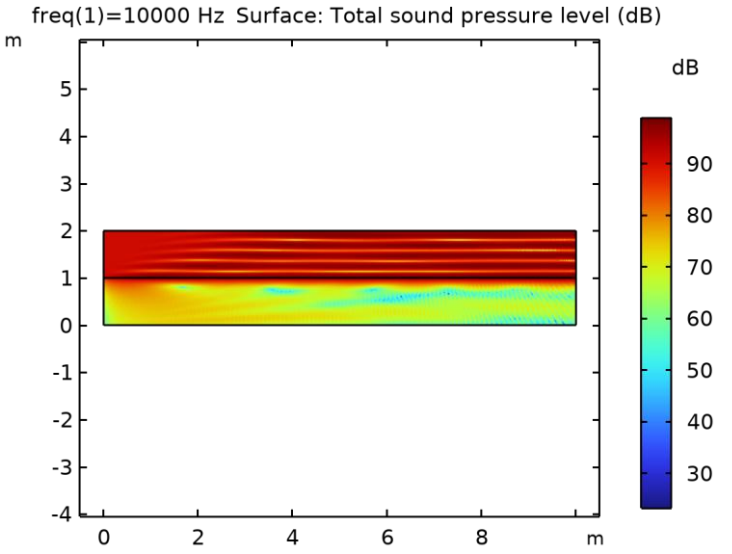
4.3 PLOT GROUPS

4.3.1 Acoustic Pressure (acpr)



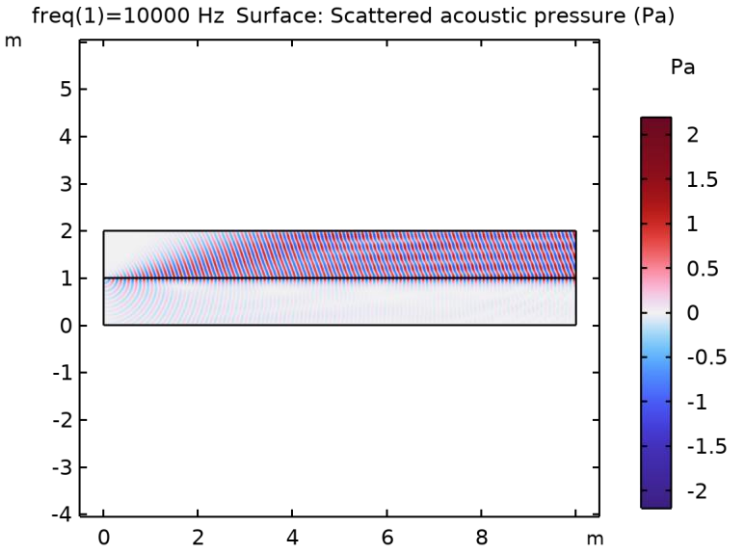
Surface: Total acoustic pressure (Pa)

4.3.2 Sound Pressure Level (acpr)



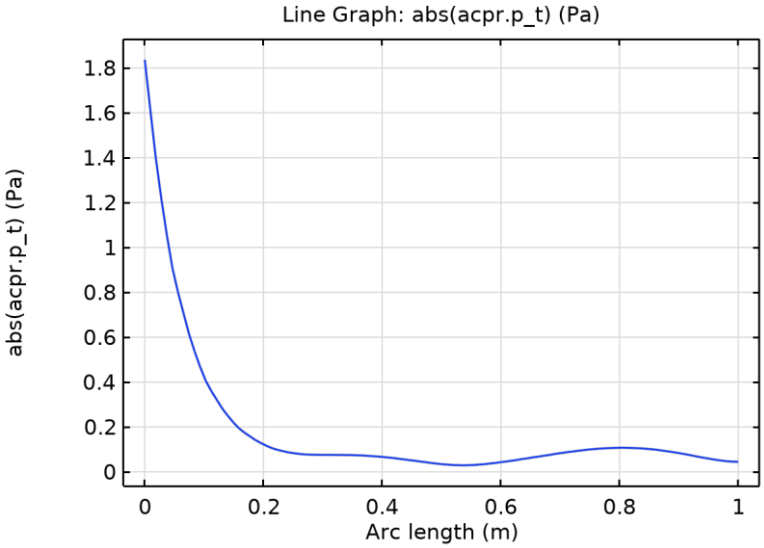
Surface: Total sound pressure level (dB)

4.3.3 Acoustic Pressure (acpr) 1



Surface: Scattered acoustic pressure (Pa)

4.3.4 1D Plot Group 4



Line Graph: abs(acpr.p_t) (Pa)

Hw5.3

Report date	Nov 16, 2025, 1:21:15 PM

Contents

1 Global Definitions

Date	Nov 16, 2025, 1:20:39 PM

GLOBAL SETTINGS

Name	Hw5.3.mph
Path	\\clusterfsnew.ceas1.uc.edu\students\brooksl\desktop\hw5.3.mph
Version	COMSOL Multiphysics 6.3 (Build: 420)

USED PRODUCTS

COMSOL Multiphysics
Acoustics Module

COMPUTER INFORMATION

CPU	Intel64 Family 6 Model 198 Stepping 2, 28 cores, 63.46 GB RAM
Operating system	Windows 11

1.1 PARAMETERS

PARAMETERS 1

Name	Expression	Value	Description
width	2[cm]	0.02 m	
height	1[cm]	0.01 m	

2 Component 1

SETTINGS

Description	Value
Unit system	Same as global system (SI)

2.1 DEFINITIONS

2.1.1 Coordinate Systems

Boundary System 1

Coordinate system type	Boundary system
Tag	sys1

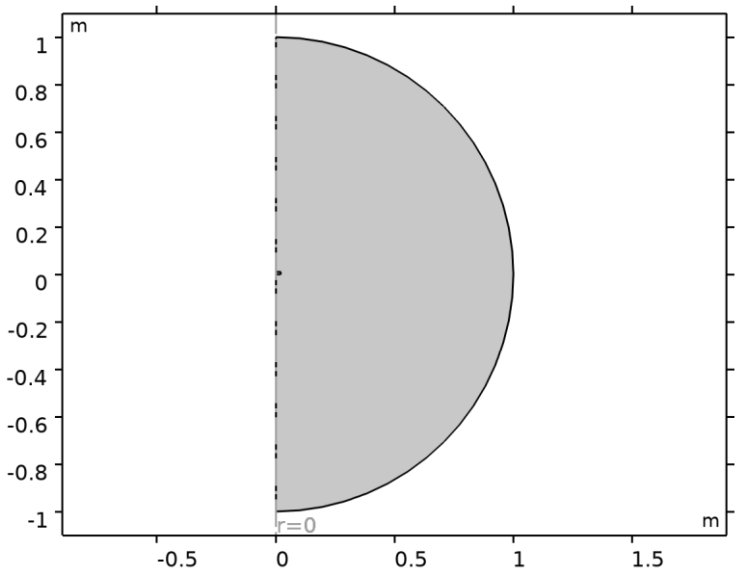
COORDINATE NAMES

First	Second	Third
t1	to	n

SETTINGS

Description	Value
Axis	phi

2.2 GEOMETRY 1



Geometry 1

UNITS

Length unit	m

Angular unit	deg

GEOMETRY STATISTICS

Description	Value
Space dimension	2
Number of domains	1
Number of boundaries	7
Number of vertices	7

2.2.1 Rectangle 1 (r1)

SIZE AND SHAPE

Description	Value
Width	width
Height	height

POSITION

Description	Value
Position	{0, 0}

2.2.2 Circle 1 (c1)

SIZE AND SHAPE

Description	Value
Radius	1

POSITION

Description	Value
Position	{0, 0}

2.2.3 Difference 1 (dif1)

INPUT OBJECTS

Description	Value
Objects to add	geom1, Geometry geom1: Object: c1
Objects to subtract	geom1, Geometry geom1: Object: r1

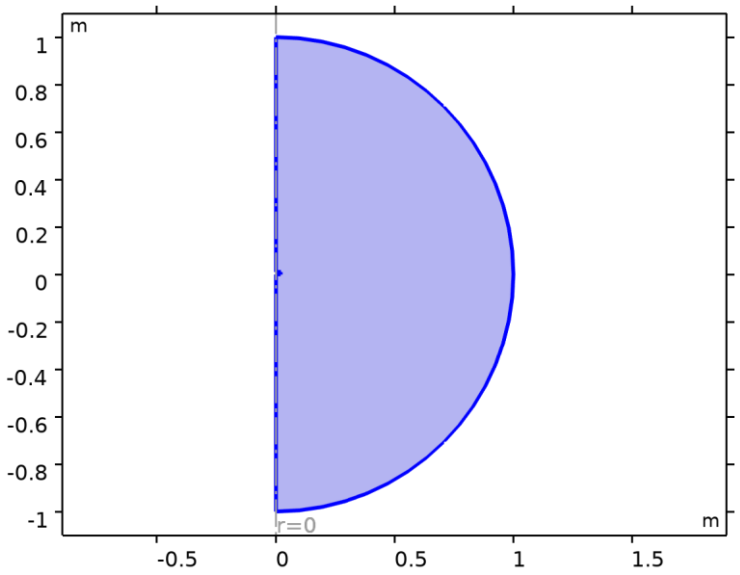
2.2.4 Form Union (fin)

INFORMATION

Description	Value
Build message	Formed union of 1 solid object. Union has 1 domain, 7 boundaries, and 7 vertices.

2.3 MATERIALS

2.3.1 air



air

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

MATERIAL PARAMETERS

Name	Value	Unit	Property group
Density	1.15	kg/m³	Basic
Speed of sound	343	m/s	Basic

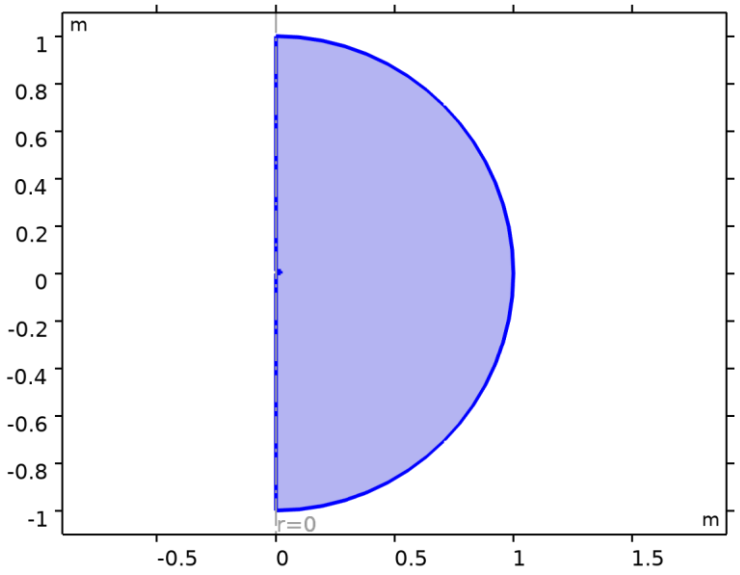
BASIC

Description	Value	Unit
Density	1.15	kg/m³
Speed of sound	343	m/s

2.4 PRESSURE ACOUSTICS, FREQUENCY DOMAIN

USED PRODUCTS

COMSOL Multiphysics
Acoustics Module



Pressure Acoustics, Frequency Domain

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

EQUATIONS

$$\nabla \cdot \left(-\frac{1}{\rho_c}(\nabla p_t - \mathbf{q}_d)\right) - \frac{k_{eq}^2 p_t}{\rho_c} = Q_m$$

$$p_t = p + p_b$$

$$k_{eq}^2 = \left(\frac{\omega}{c_c}\right)^2 - k_m^2$$

2.4.1 Interface Settings

Physics Symbols

SETTINGS

Description	Value
Enable physics symbols	On

Discretization

SETTINGS

Description	Value
Element order	Quadratic Lagrange

Physics-Controlled Mesh

SETTINGS

Description	Value
Maximum mesh element size control parameter	From study
Number of mesh elements per wavelength	Automatic

Pressure Acoustics Equation Settings

SETTINGS

Description	Value
Azimuthal mode number	0

Global Port Settings

SETTINGS

Description	Value
Port sweep settings	No port sweep
Mode shape normalization	Amplitude normalization

Sound Pressure Level Settings

SETTINGS

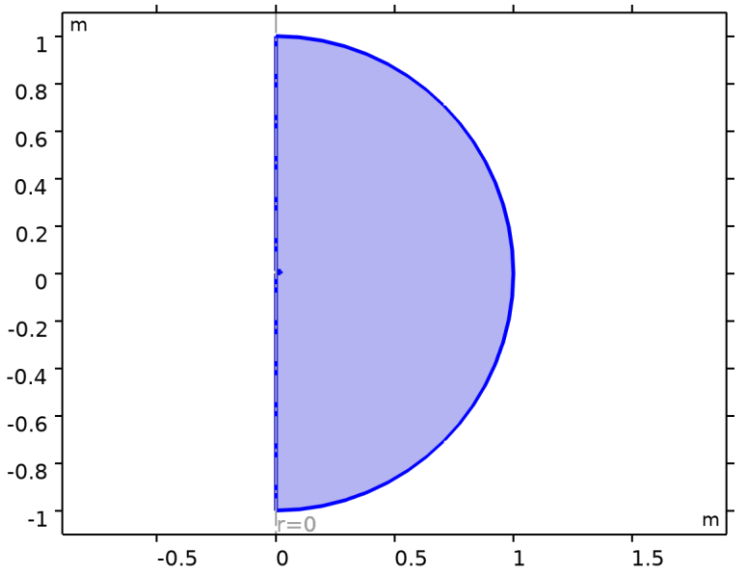
Description	Value
Reference pressure for the sound pressure level	Use reference pressure for air

Typical Wave Speed for Perfectly Matched Layers

SETTINGS

Description	Value	Unit
Typical wave speed for perfectly matched layers	real(acpr.c_c)	m/s

2.4.2 Pressure Acoustics 1



Pressure Acoustics 1

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

EQUATIONS

$$\nabla \cdot \left(-\frac{1}{\rho_c}\left(\nabla p_t - \mathbf{q}_d\right)\right) - \frac{k_{eq}^2 p_t}{\rho_c} = Q_m$$

$$p_t = p + p_b$$

$$k_{eq}^2 = \left(\frac{\omega}{c_c}\right)^2 - k_m^2$$

$$c_c = c, \quad \rho_c = \rho$$

Pressure Acoustics Model

SETTINGS

Description	Value
Fluid model	Linear elastic
Specify	Density and speed of sound
Speed of sound	From material
Density	From material

Model Input

SETTINGS

Description	Value	Unit
Temperature	User defined	
Temperature	293.15	K
Absolute pressure	User defined	
Absolute pressure	1.0133E5	Pa

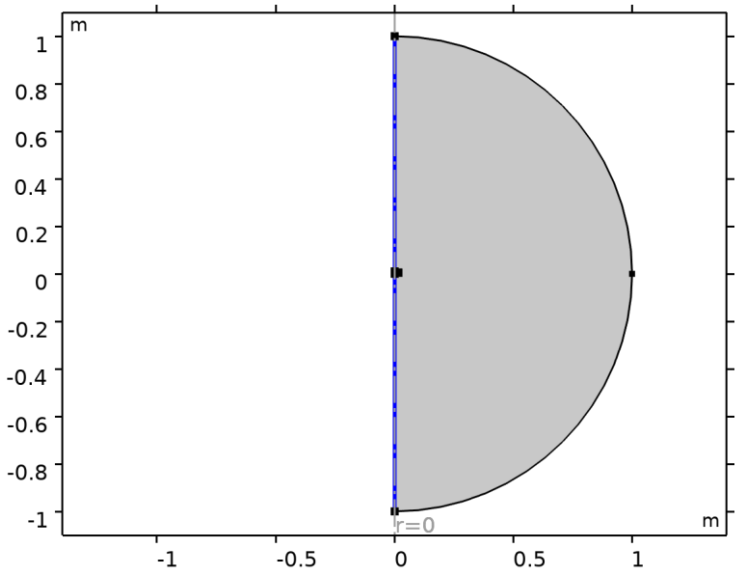
USED PRODUCTS

COMSOL Multiphysics

PROPERTIES FROM MATERIAL

Property	Material	Property group
Density	air	Basic
Speed of sound	air	Basic

2.4.3 Axial Symmetry 1



Axial Symmetry 1

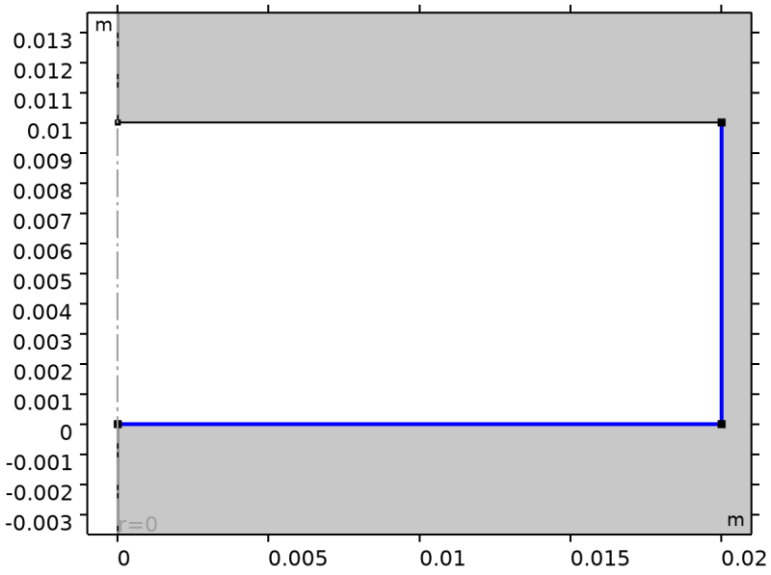
SELECTION

Geometric entity level	Boundary
Selection	Geometry geom1: Dimension 1: All boundaries

USED PRODUCTS

COMSOL Multiphysics

2.4.4 Sound Hard Boundary (Wall) 1



Sound Hard Boundary (Wall) 1

SELECTION

Geometric entity level	Boundary
Selection	Geometry geom1: Dimension 1: All boundaries

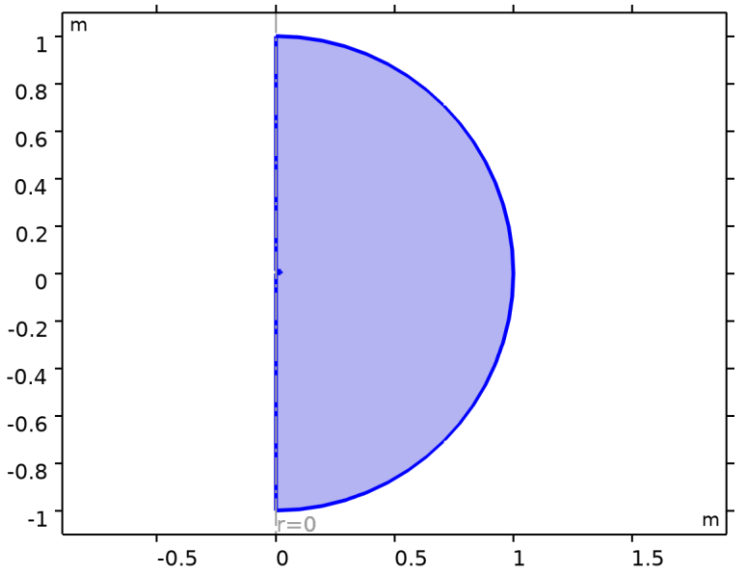
EQUATIONS

$$-\mathbf{n}\cdot\left(-\frac{1}{\rho_c}(\nabla p_t-\mathbf{q}_d)\right)=0$$

USED PRODUCTS

COMSOL Multiphysics

2.4.5 Initial Values 1



Initial Values 1

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: All domains

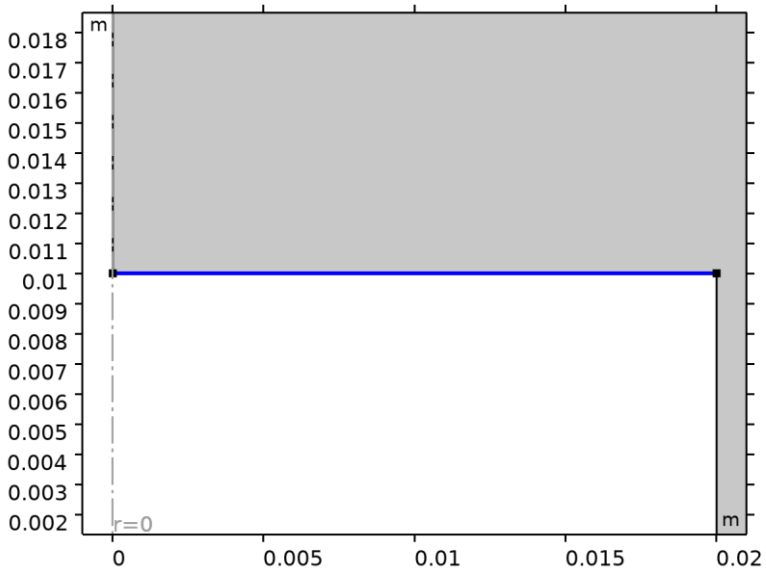
SETTINGS

Description	Value	Unit
Acoustic pressure	0	Pa

USED PRODUCTS

COMSOL Multiphysics

2.4.6 Normal Velocity 1



Normal Velocity 1

SELECTION

Geometric entity level	Boundary
Selection	Geometry geom1: Dimension 1: Boundary 4

EQUATIONS

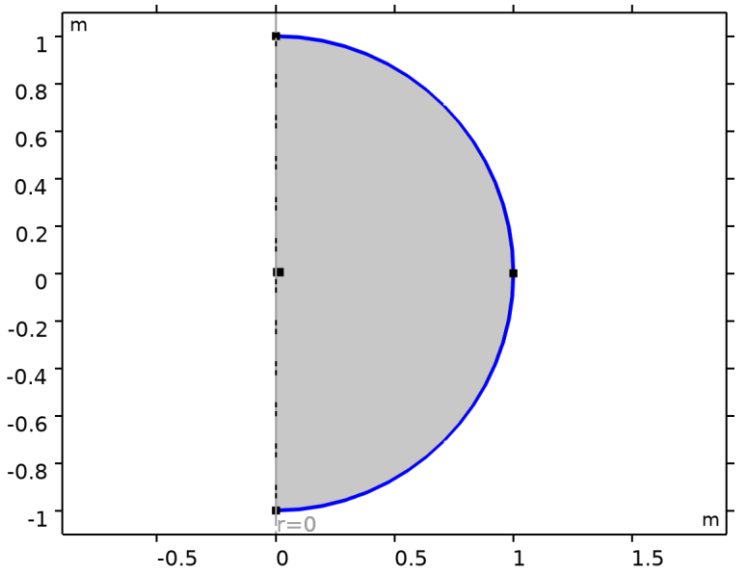
$$-\mathbf{n}\cdot\left(-\frac{1}{\rho_c}(\nabla p_t-\mathbf{q}_d)\right)=i\omega v_n$$

Normal Velocity

SETTINGS

Description	Value	Unit
Type	Inward velocity	
Inward velocity	0.01	m/s

2.4.7 Spherical Wave Radiation 1



Spherical Wave Radiation 1

SELECTION

Geometric entity level	Boundary
Selection	Geometry geom1: Dimension 1: Boundaries 6–7

EQUATIONS

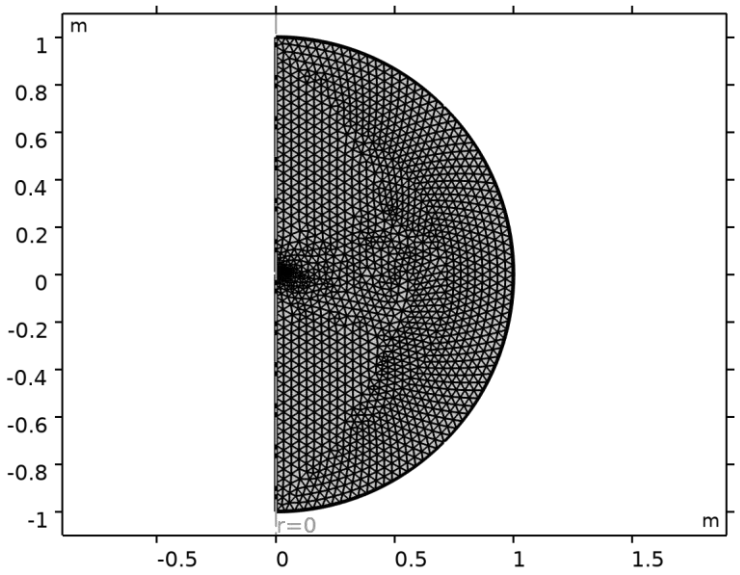
$$-\mathbf{n}\cdot\left(-\frac{1}{\rho_c}(\nabla p_t-\mathbf{q}_d)\right)+\underbrace{\left(ik_{eq}+\frac{1}{r_{rf}}\right)\frac{p}{\rho_c}-\frac{r_{rf}\Delta_{||}p}{2\rho_c(1+ik_{eq}r_{rf})}}=Q_i$$

$$r_{rf}=|(\mathbf{x}-\mathbf{r}_0)|$$

USED PRODUCTS

COMSOL Multiphysics

2.5 MESH 1



Mesh 1

2.5.1 Size (size)

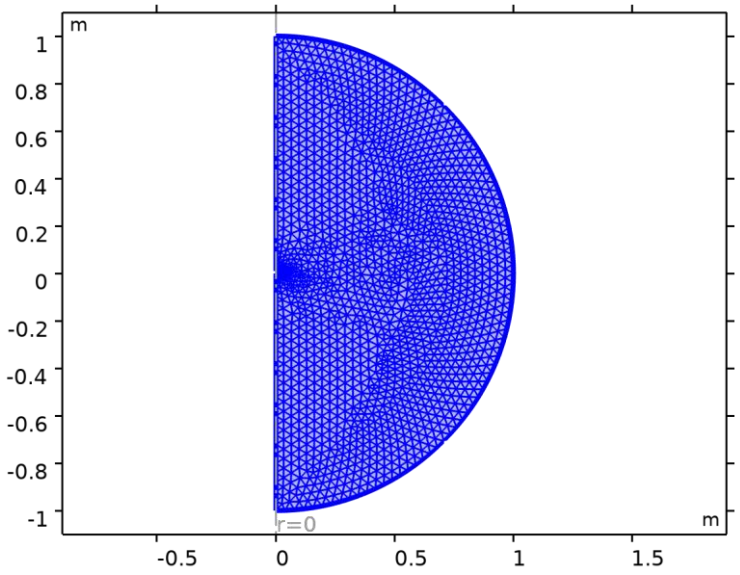
SETTINGS

Description	Value
Maximum element size	0.04
Minimum element size	2E-5
Curvature factor	0.25
Maximum element growth rate	1.2
Predefined size	Extra fine
Custom element size	Custom

2.5.2 Size Expression 1 (se1)

SELECTION

Geometric entity level	Domain
Selection	Geometry geom1: Dimension 2: Domain 1



Size Expression 1

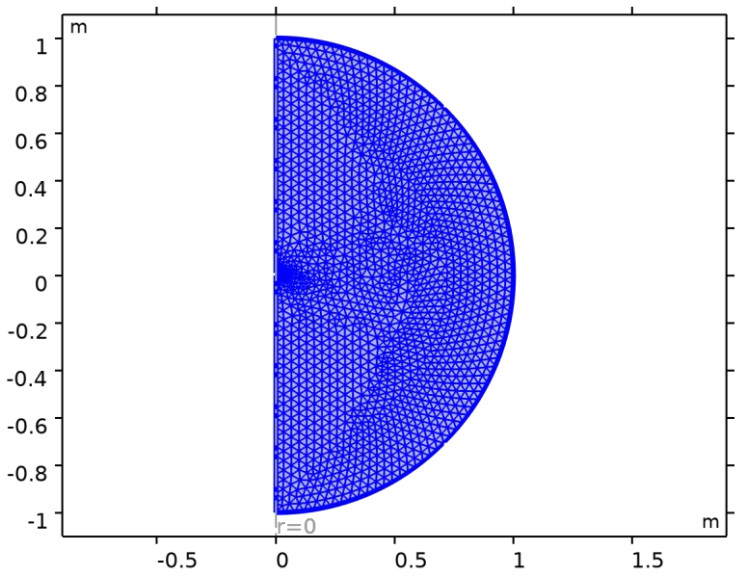
SETTINGS

Description	Value
Evaluate on	Initial expression
Study step	Study 1: Frequency Domain
Size expression	subst(real(acpr.c_c), acpr.freq, freqmax)/freqmax/5
Reevaluate with updated model	

2.5.3 Free Triangular 1 (ftri1)

SELECTION

Geometric entity level	Domain
Selection	Remaining



Free Triangular 1

SETTINGS

Description	Value
Number of iterations	4
Maximum element depth to process	4

INFORMATION

Description	Value
Last build time	< 1 second
Built with	COMSOL 6.3.0.420 (win64), Nov 16, 2025, 12:16:42 PM

3 Study 1

COMPUTATION INFORMATION

Computation time	1 s

3.1 FREQUENCY DOMAIN

Frequencies (Hz)
1000

STUDY SETTINGS

Description	Value
Include geometric nonlinearity	Off

SETTINGS

Description	Value
Frequencies	1000

PHYSICS AND VARIABLES SELECTION

Key	Solve for
Pressure Acoustics, Frequency Domain (acpr)	On

STORE IN OUTPUT

Interface	Output	Selection
Pressure Acoustics, Frequency Domain (acpr)	Physics controlled	

MESH SELECTION

Component	Mesh
Component 1	Mesh 1

3.2 SOLVER CONFIGURATIONS

3.2.1 Solution 1

Compile Equations: Frequency Domain (st1)

STUDY AND STEP

Description	Value
Use study	Study 1
Use study step	Frequency Domain

Dependent Variables 1 (v1)

GENERAL

Description	Value
Defined by study step	Step 1: Frequency Domain

INITIAL VALUE CALCULATION CONSTANTS

Constant name	Initial-value source
freq	1000[Hz]

Acoustic Pressure (comp1.p) (comp1_p)

GENERAL

Description	Value
Field components	comp1.p

Stationary Solver 1 (s1)

GENERAL

Description	Value
Defined by study step	Step 1: Frequency Domain

RESULTS WHILE SOLVING

Description	Value
Probes	None

Advanced (aDef)

ASSEMBLY SETTINGS

Description	Value
Reuse sparsity pattern	On
Allow complex-valued output from functions with real input	On

Parametric 1 (p1)

GENERAL

Description	Value
Defined by study step	Step 1: Frequency Domain
Run continuation for	No parameter

PARAMETERS

Parameter name	Parameter value list	Parameter unit
freq	1000	Hz

Fully Coupled 1 (fc1)

GENERAL

Description	Value

Description	Value
Linear solver	Direct

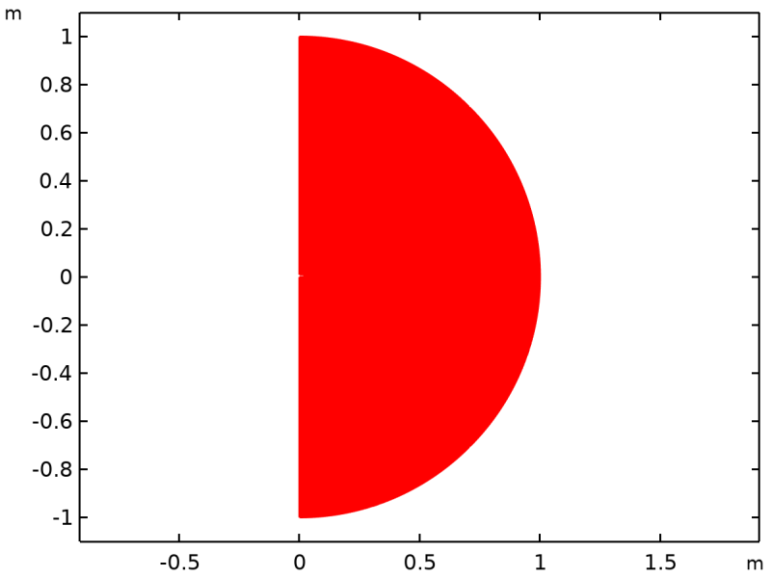
4 Results

4.1 DATASETS

4.1.1 Study 1/Solution 1

SOLUTION

Description	Value
Solution	Solution 1 (sol1)
Component	Component 1 (comp1)



Dataset: Study 1/Solution 1

4.1.2 Revolution 2D 1

DATA

Description	Value
Dataset	Study 1/Solution 1 (sol1)

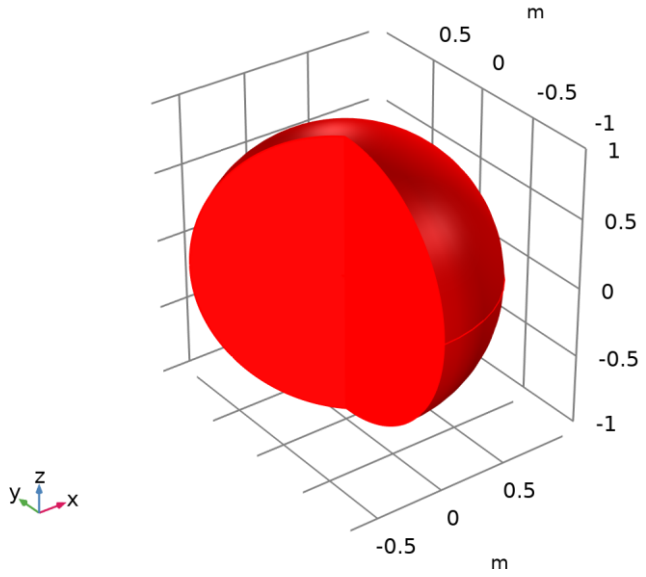
AXIS DATA

Description	Value
Axis entry method	Two points
Points	{{0, 0}, {0, 1}}

REVOLUTION LAYERS

Description	Value
Start angle	-90

Description	Value
Revolution angle	225



Dataset: Revolution 2D 1

4.2 DERIVED VALUES

4.2.1 Line Integration 1

OUTPUT

Evaluated in	Table 1

DATA

Description	Value
Dataset	Study 1/Solution 1 (sol1)

EXPRESSIONS

Expression	Unit	Description
acpr.I_mag	W	Intensity magnitude

INTEGRATION SETTINGS

Description	Value
Integration order	4
Compute surface integral	On

4.3 TABLES

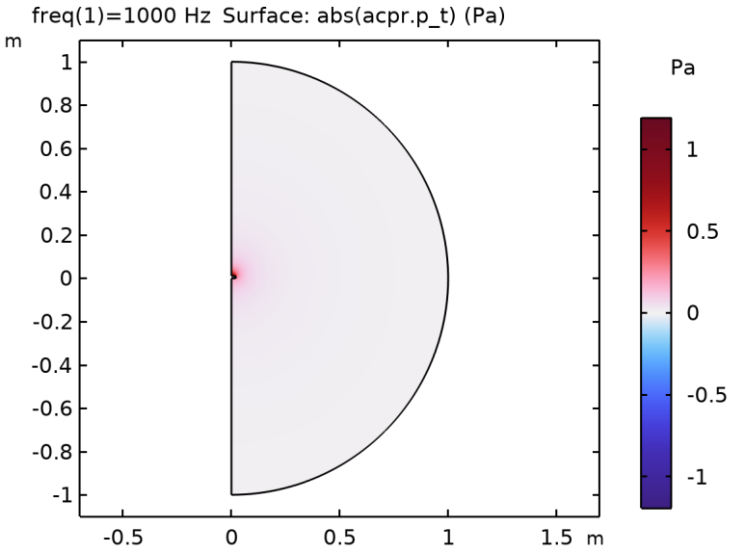
4.3.1 Table 1

Line Integration 1

freq (Hz)	Intensity magnitude (W)
1000	8.2901E-7

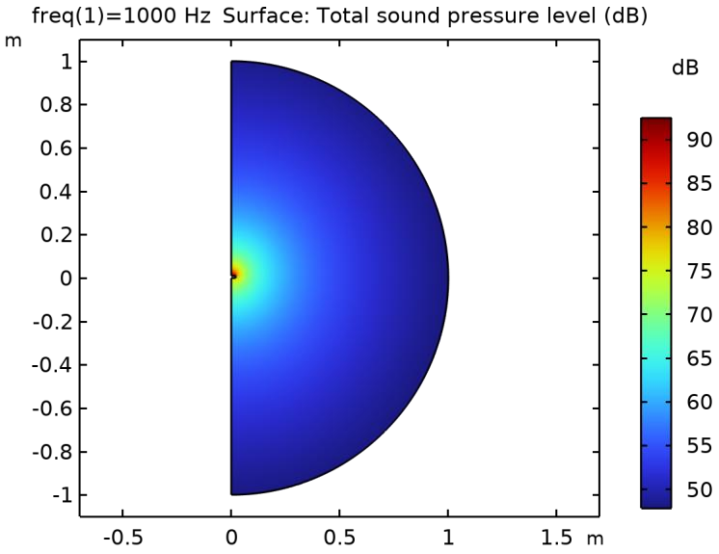
4.4 PLOT GROUPS

4.4.1 Acoustic Pressure (acpr)



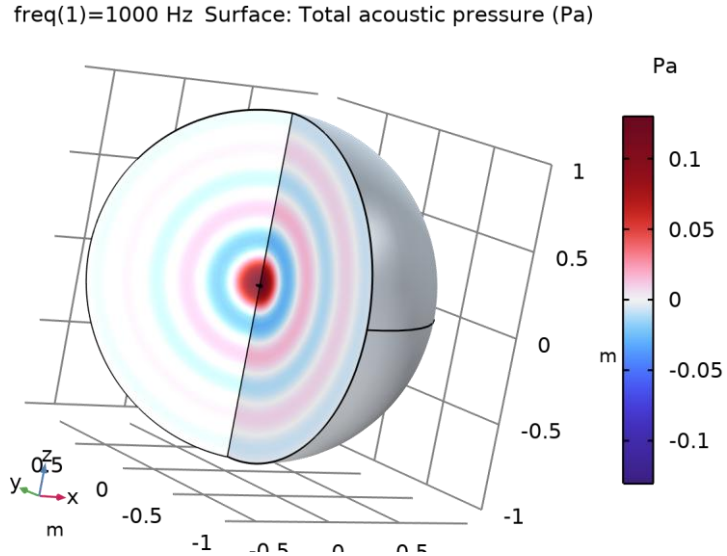
Surface: abs(acpr.p_t) (Pa)

4.4.2 Sound Pressure Level (acpr)



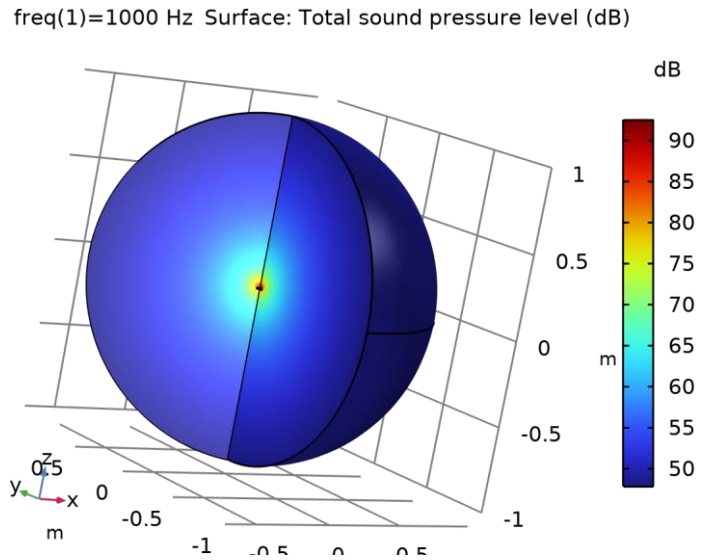
Surface: Total sound pressure level (dB)

4.4.3 Acoustic Pressure, 3D (acpr)



Surface: Total acoustic pressure (Pa)

4.4.4 Sound Pressure Level, 3D (acpr)



Surface: Total sound pressure level (dB)

4.5 EVALUATION GROUPS

4.5.1 Evaluation Group 1

DATA

Description	Value
Dataset	Study 1/Solution 1 (sol1)

FEATURES

Point Evaluation 1

RESULTS

freq (Hz)	abs(acpr.p_t) (Pa), Point: 1	abs(acpr.p_t) (Pa), Point: 3	abs(acpr.p_t) (Pa), Point: 4	abs(acpr.p_t) (Pa), Point: 7	Total sound pressure level (dB), Point: 1	Total sound pressure level (dB), Point: 3	Total sound pressure level (dB), Point: 4	Total sound pressure level (dB), Point: 7
1000	0.0071401	1.1931	0.0074765	0.0070062	48.043	92.502	48.443	47.879

Point Evaluation 1

EXPRESSIONS

Expression	Unit	Description
abs(acpr.p_t)	Pa	

Expression	Unit	Description
acpr.Lp_t	dB	Total sound pressure level