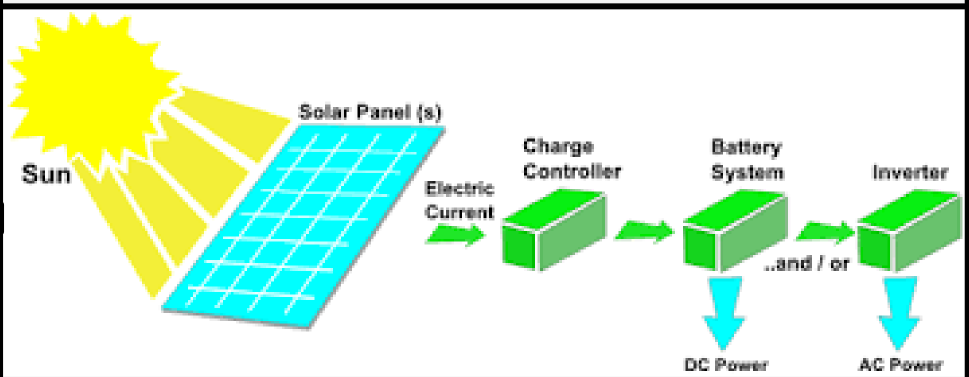
Design and Development of Acoustic energy harvester(AEH)

Motto :

"To convert acoustical sound wave to electrical energy with the help of piezoelectricity and sound pressure amplification which is done by Helmholtz resonator and making it usable in practical purposes (large scale)"

Need of "Acoustic Energy Harvester"

*Electricity is produced majorly from coal, fossil fuels etc. But these sources are **non-renewable** and limited. So people have been trying from ages to use other sources like solar and wind since they are unlimited(we can say) and renewable. So one such thing is **sound** (undesired sound which is noise) which is we can say present in unlimited in atmosphere due to vehicles, industries, railways, airways etc. But the tricky thing with sound is it has **low energy density** compared to solar and wind. This can be overcome by **pressure amplification** which can be done with the help of **"Helmholtz Resonator".***

<table>
<tr><th>Solar Energy Harvesting</th><th>Wind Energy Harvesting</th><th>Thermal Power Plants.</th></tr>
<tr><td>
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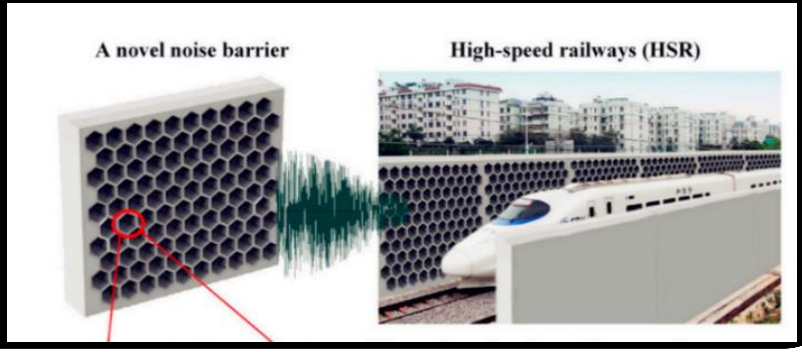
Innovation

Sound Energy Harvesting

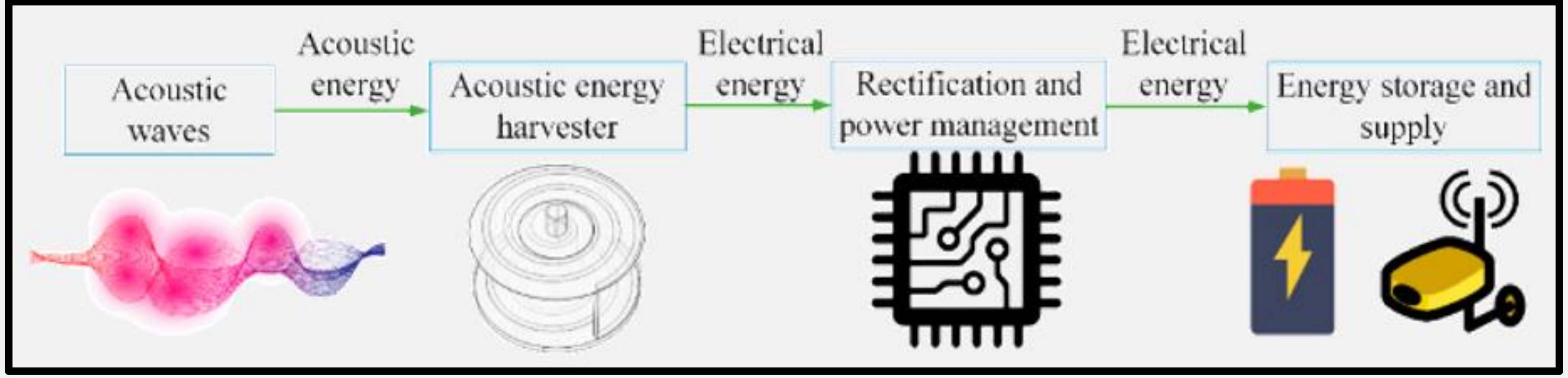


Acoustic Energy

- Acoustic Energy is defined as the energy that is related to mechanical vibrations from its constituents.
- Acoustic sound waves are mechanical waves that possess energy and can be generated by many noise sources.

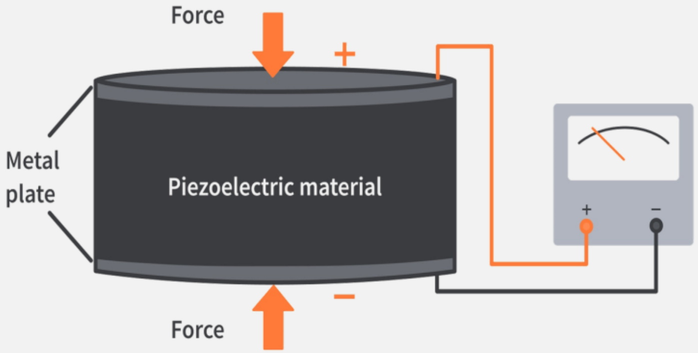
Sound Harvesting Mechanism:

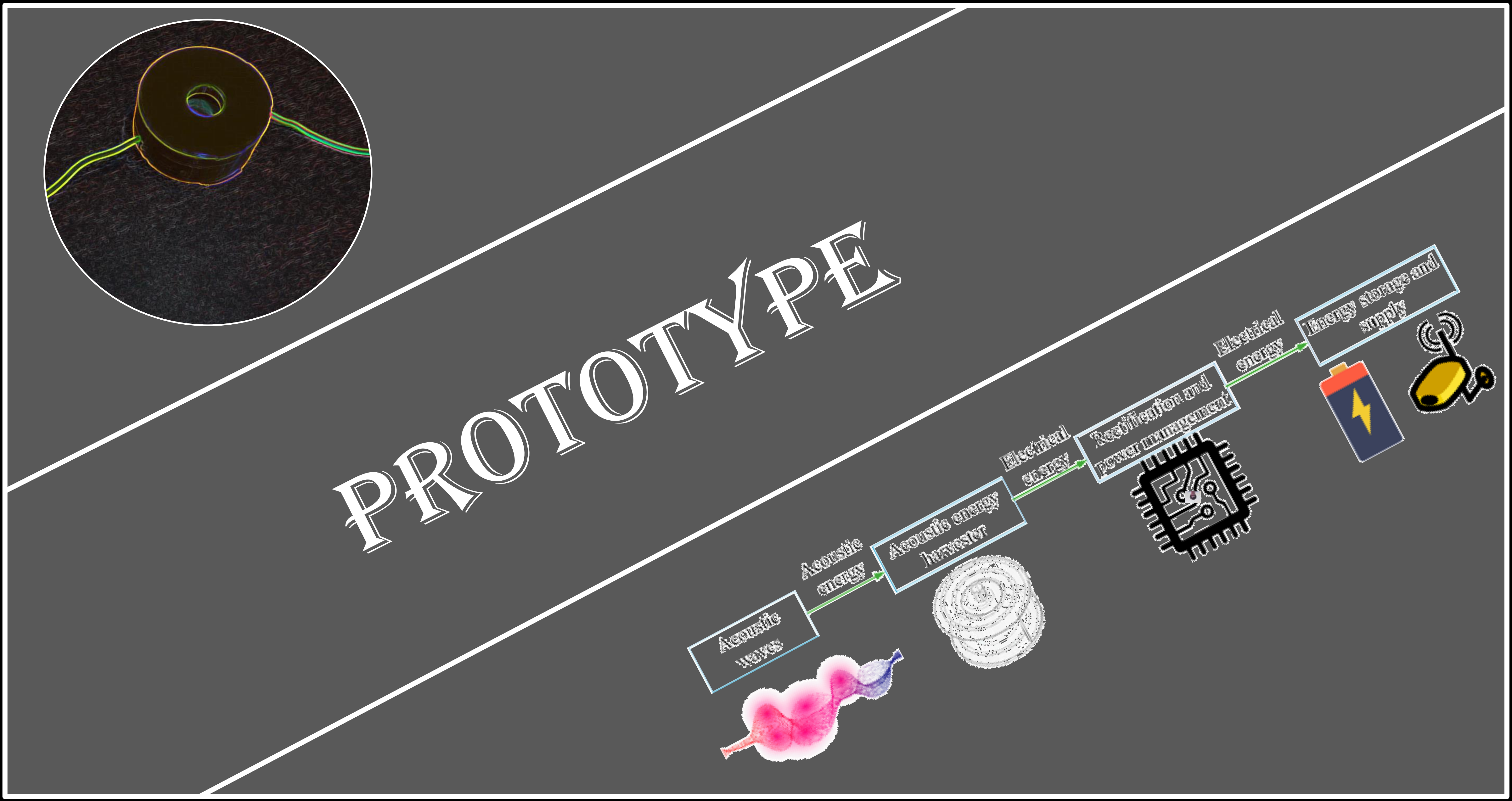
SCHEMATIC DIAGRAM OF AN ACOUSTIC ENERGY HARVESTING SYSTEM



<u>PIEZO ELECTRIC MATERIAL :</u>

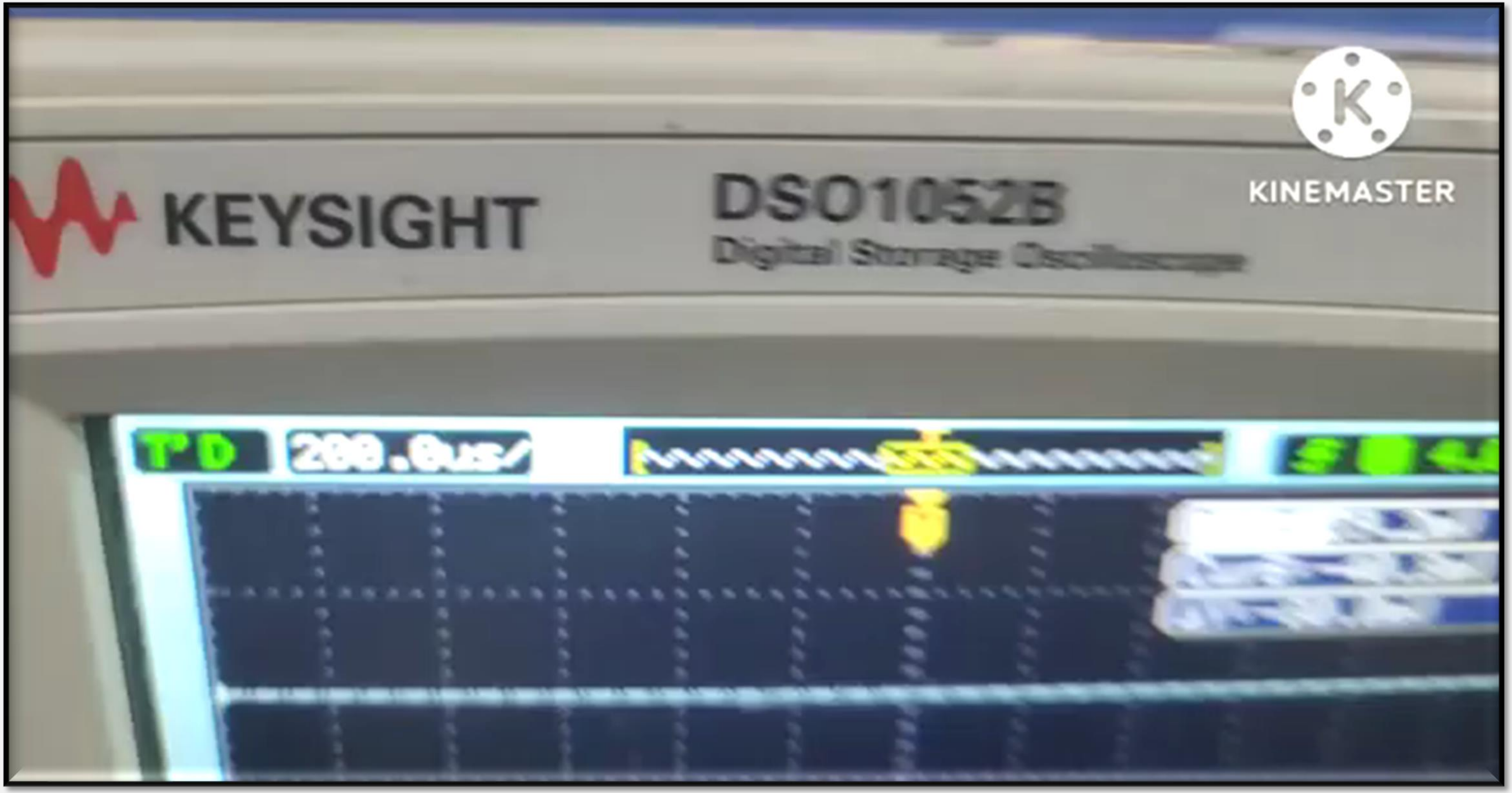
Piezoelectric materials are widely referred to as "smart" materials because they can transduce mechanical pressure acting on them to electrical signals and vice versa. They are extensively utilized in harvesting mechanical energy from vibrations, human motion, mechanical loads, etc., and converting them into electrical energy for low power devices.



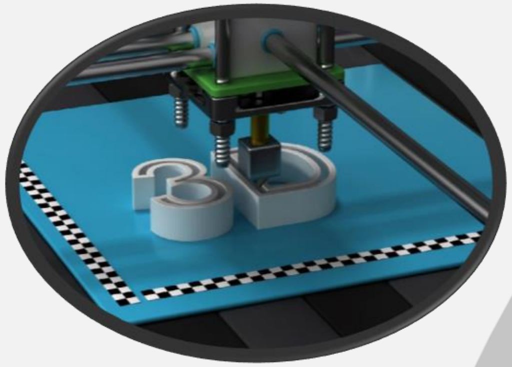

PROTOTYPE
Acoustic waves
Acoustic energy
Acoustic energy harvester
Electrical energy
Rectification and power management
Electrical energy
Energy storage and supply

Demonstration:

[Link](#)

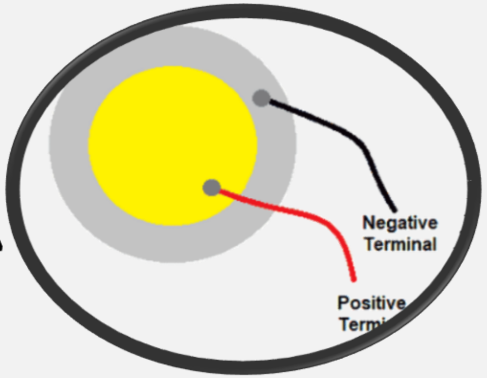


Materials Used:



3d
Printin
g

Piezo
plate



Speake
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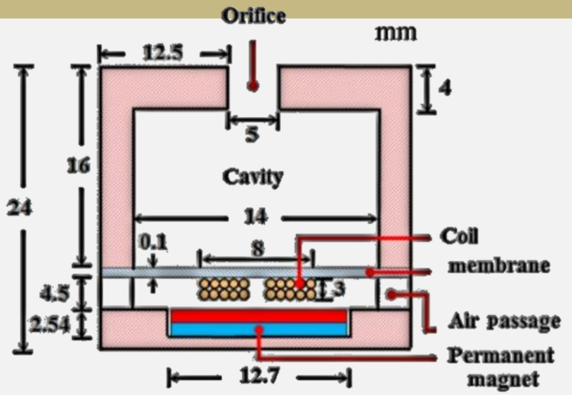
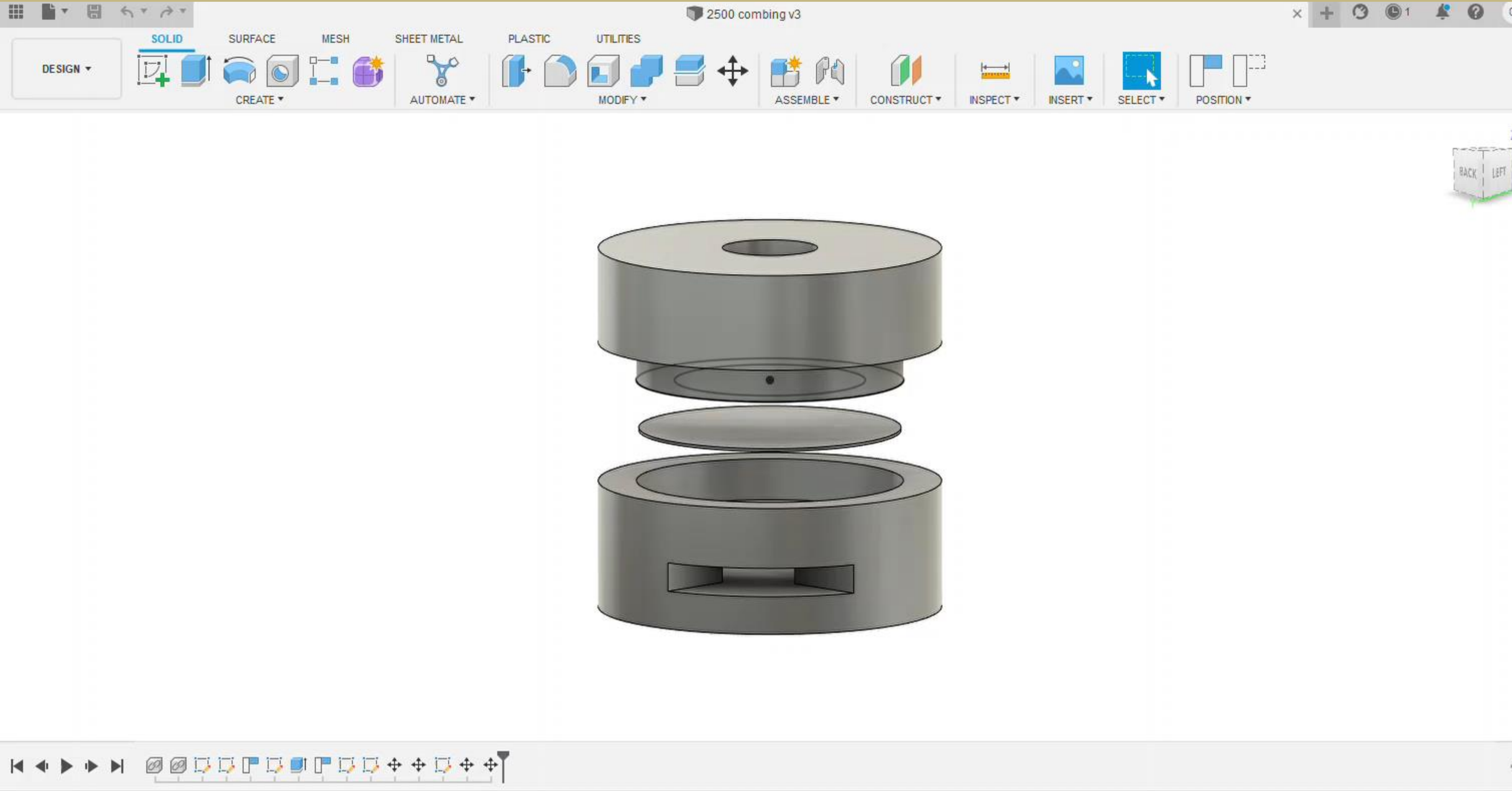


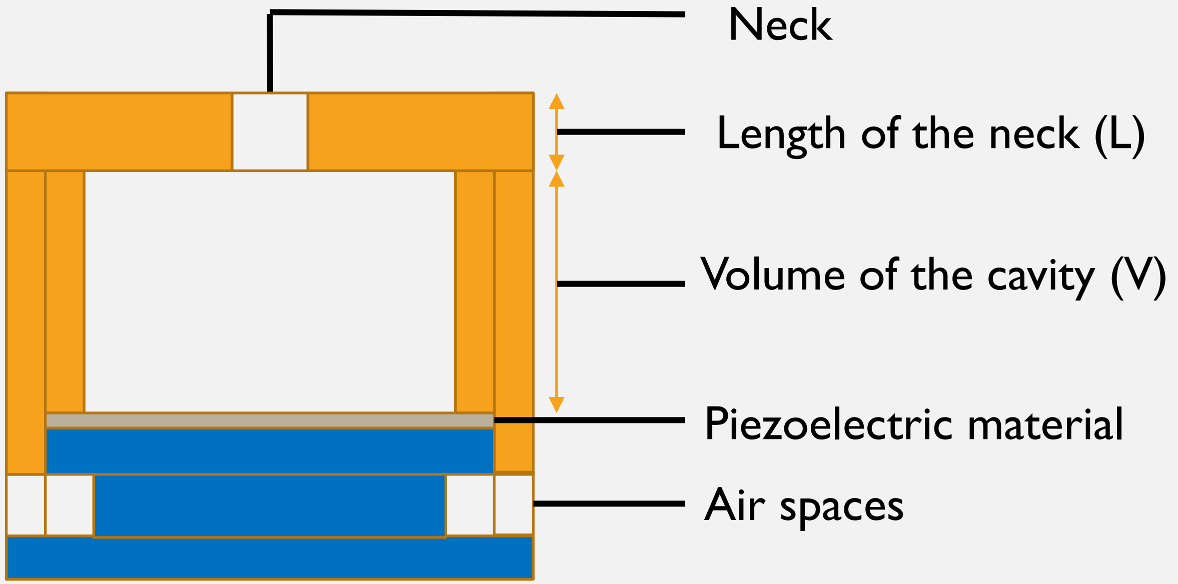
Acoustic Energy
harvester

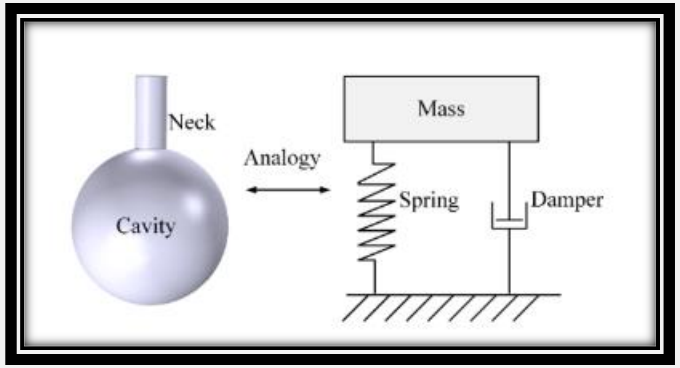
Autocad Fusion 360 Model (3-D view)



Harvesting cell

Cross section of Helmholtz resonator





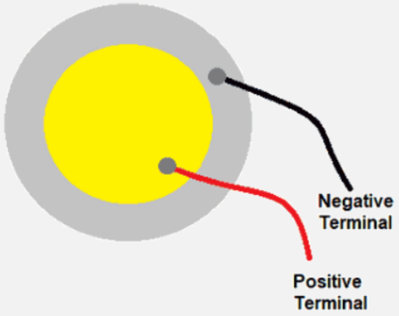
$$f_r = \frac{c_0}{2\pi}\sqrt{\frac{S}{V(L+1.7r)}}$$

End correction factor

Co = speed of sound
V = volume of the cylinder

S = surface area of neck
r = radius of the neck
L = Length of the neck

After Soldering



$$v_{sound} = \sqrt{\frac{\gamma RT}{M}}$$ where

γ = adiabatic constant
R = gas constant
M = molecular mass of gas
T = absolute temperature

Calculations.

- Calculations can be easily done with the help of a piece of code in one click for solving Helmholtz resonator frequency equation to get one desired value by fixing values of other parameters. Here a python 3.5 code is used to calculate frequency for fixed values (assumed and given).
- Taking temperature in surroundings(Palakkad) as 27C, then Co = 347.22193 m/s

We take

- Radius of neck is 5mm.
- Length of neck as 5mm.
- Radius of resonating volume as 10mm.
- Height of the resonating volume =5.354194mm

$$f_r = \frac{c_0}{2\pi}\sqrt{\frac{S}{V(L+1.7r)}}$$

End correction factor

We get the frequency of F = 3250 Hz

In [5]:

```
# To get the frequency of resonator
# f = (Co/2pi)(sqrt(S/V(L + 1.7 r)))
r = float(input("Enter radius of neck:"))
L = float(input("Enter length of the neck:"))
R = float(input("Enter radius of resonating volume:"))
H = float(input("Enter height of resonating volume:"))
Co = float(input("Enter speed of sound:"))
S = (22 / 7) * (r ** 2)
V = (22 / 7) * (R ** 2) * (H)
f = (Co * 7 / 44) * ((S / (V * (L + 1.7 * r))) ** (1 / 2))
print("FREQUENCY (in hz): ", f)
```

```
Enter radius of neck:0.005
Enter length of the neck:0.005
Enter radius of resonating volume:0.01
Enter height of resonating volume:0.00534194
Enter speed of sound:347.22193
FREQUENCY (in hz):  3252.4162890329644
```

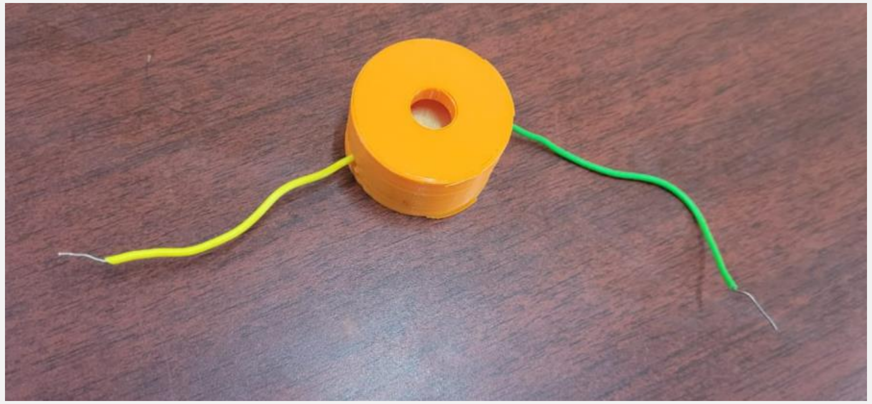
Design Building

- Taking temperature in surroundings(Palakkad) as 27C, then Co = 347.22193 m/s

We take

- Radius of neck is 5mm.
- Length of neck as 5mm.
- Radius of resonating volume as 10mm.
- Height of the resonating volume =5.354194mm

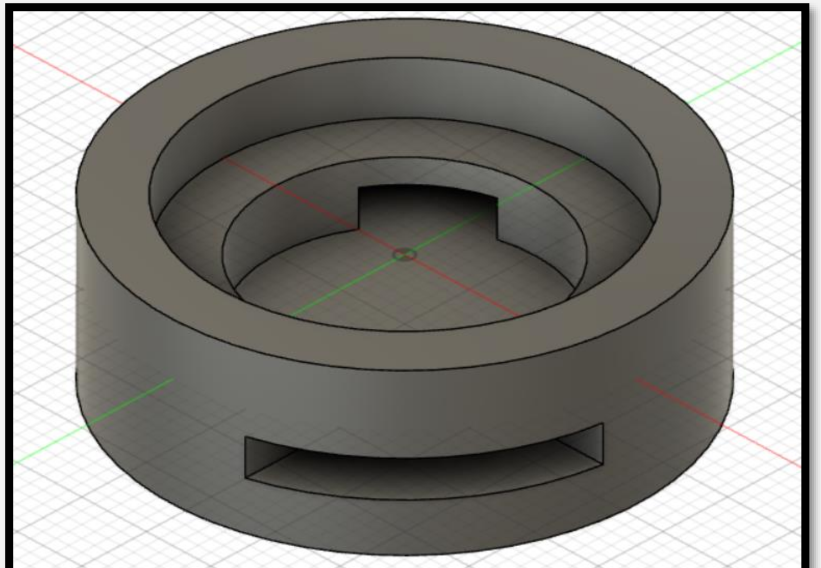
We get the frequency of F = 3250 Hz, The Helmholtz resonator shown in the side is built based on these values.



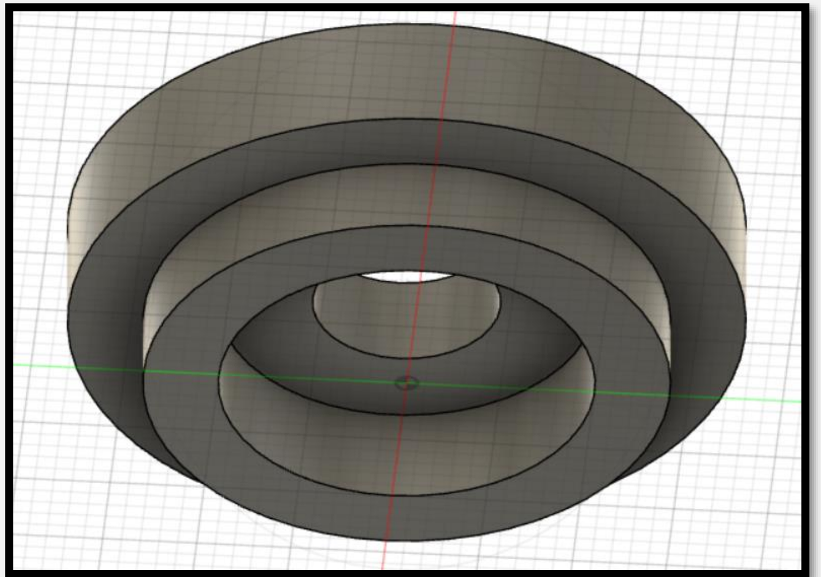
Yellow = negative
Green = positive

AUTOCAD FUSION 360 MODELS FOR FREQUENCY 3250 HZ

Base Part

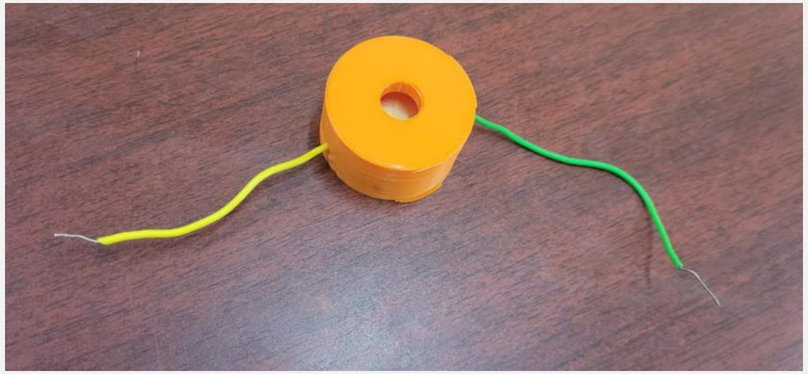


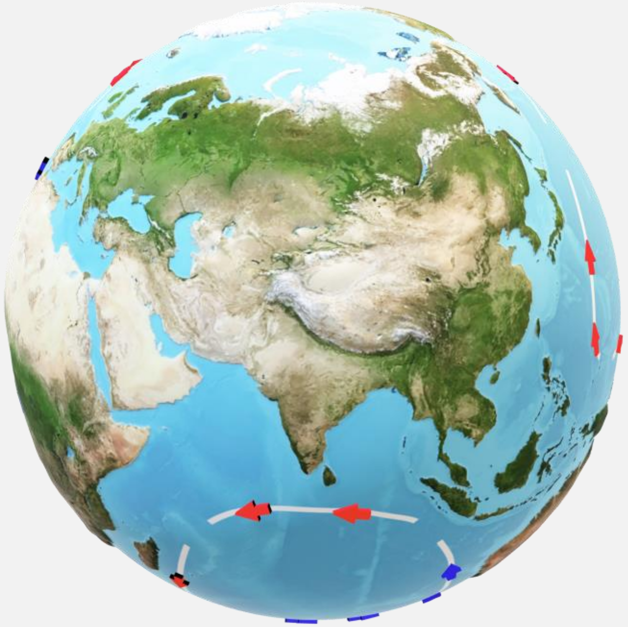
Upper part




IDEA
PROCESS
GROWTH
DEVELOPMENT
INNOVATION
VISION
CREATIVITY
INSPIRATION

Challenges (prototype to real world).





Challenges (prototype to real world).

Dust	*Efficiency(output/input)*	*Characteristic Frequency*	*Piezo electric material.*
Dust (fog, smoke, particulates) will enter into the resonator and this will initially damp the vibration of piezo and later this will lead the resonator to not work!!	*The output of a single resonator in prototype demonstration is about 1V to 2V(some times). But in the real life scenario the source of sound(noise) is not very close to the neck of resonator. This will effect the input intensity of sound(SPL).*	*Different places have different frequencies, different intensities of sound. And at the same place the frequency range will be wide enough. So we need to make and array of resonators so that a range of frequency of sound is absorbed by resonators.*	*Piezo material of designed frequency and high flexibility is need for vibration.* *Fabrication of piezo electric material of the designed frequency is one of the challenges.. Lets say highway, railway track, at traffic signal.*

Field survey.

- *The survey is measuring SPL(sound pressure level) at near by places.*
- *All recordings were made between 1pm to 4pm on Friday(working day), 16th September 2022.*

Place 1: *Wise park Traffic signal*

Location

SPL vs Frequency video

observations: *SPL is always maximum in the range of frequencies 50 Hz to 250 Hz. But there is a change in SPL at higher frequencies that is around 1000 Hz to 3000 Hz but the maximum SPL is always at lower frequencies.*

Place 2: *Railway Track*

Location

SPL vs Frequency

observations: *SPL is always maximum in the range of frequencies 50 Hz to 250 Hz. But there is a significant change in SPL at higher frequencies that is around 500 Hz to 1600 Hz but the maximum SPL is always at lower frequencies. Change is much significant compared to other places.*

Field survey.

Place 3: *Canal Pirivu*

Location, SPL vs Frequency video

observations: *SPL is always maximum in the range of frequencies 100 Hz to 300 Hz. But there is a change in SPL at higher frequencies that is around 500 Hz to 1000 Hz but the maximum SPL is always at lower frequencies.*

Place 4: *IIT Palakkad Nila Campus entrance*

Location, SPL vs Frequency video 1, SPL vs Frequency video 2

observations: *SPL is always maximum in the range of frequencies 50 Hz to 250 Hz. But there is a change in SPL at higher frequencies that is around 300 Hz to 700 Hz but the maximum SPL is always at lower frequencies. I have seen a bike travelling nearby, when break is applied the sound generated due to this is showing very significant SPL change at very high frequency.*

Place 5: *SPL measurement of motor noise of auto*

SPL vs Frequency video

observations: *There is no significant change in SPL at any level. But SPL is almost equal to lower level frequency SPL.*

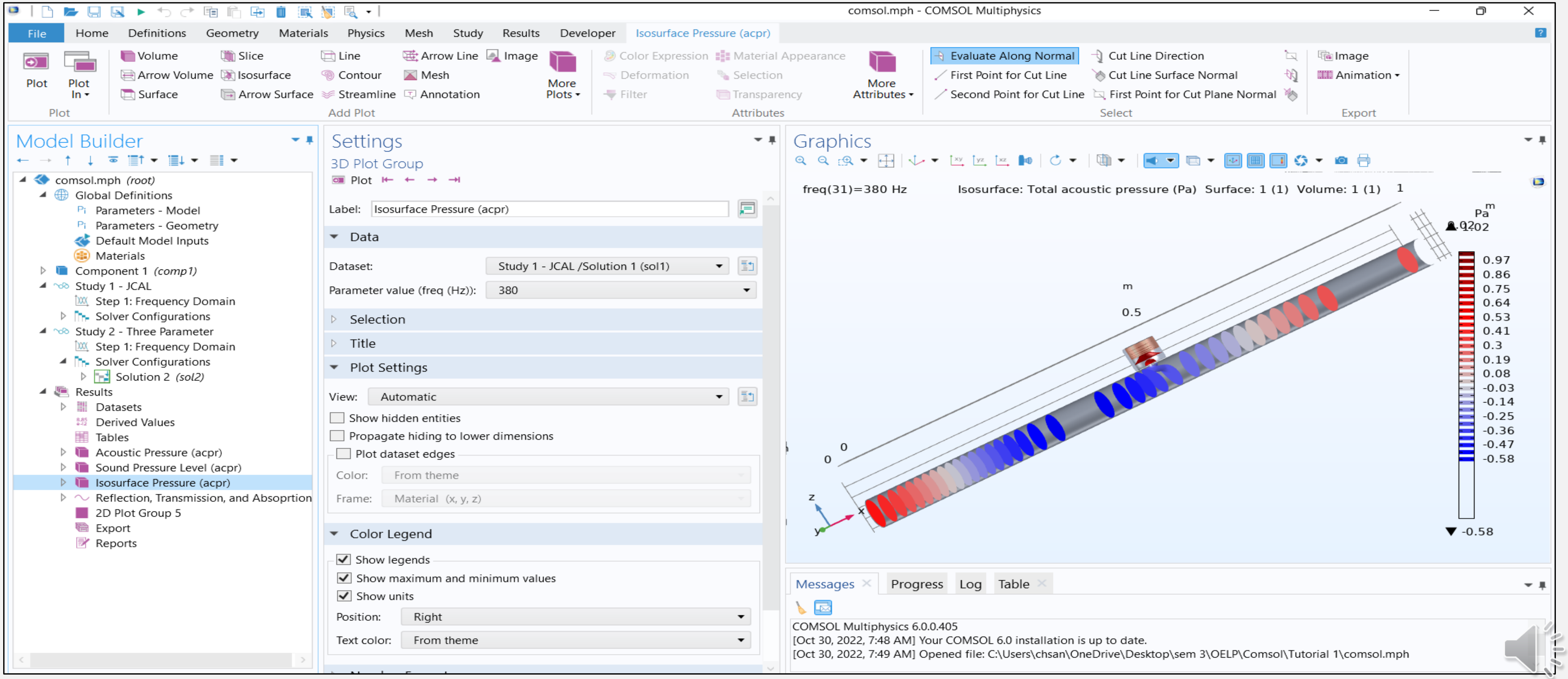
Place 6: *SPL measurement of while travelling in auto.*

SPL vs Frequency video

observations: *There is no significant change in SPL at any level.*

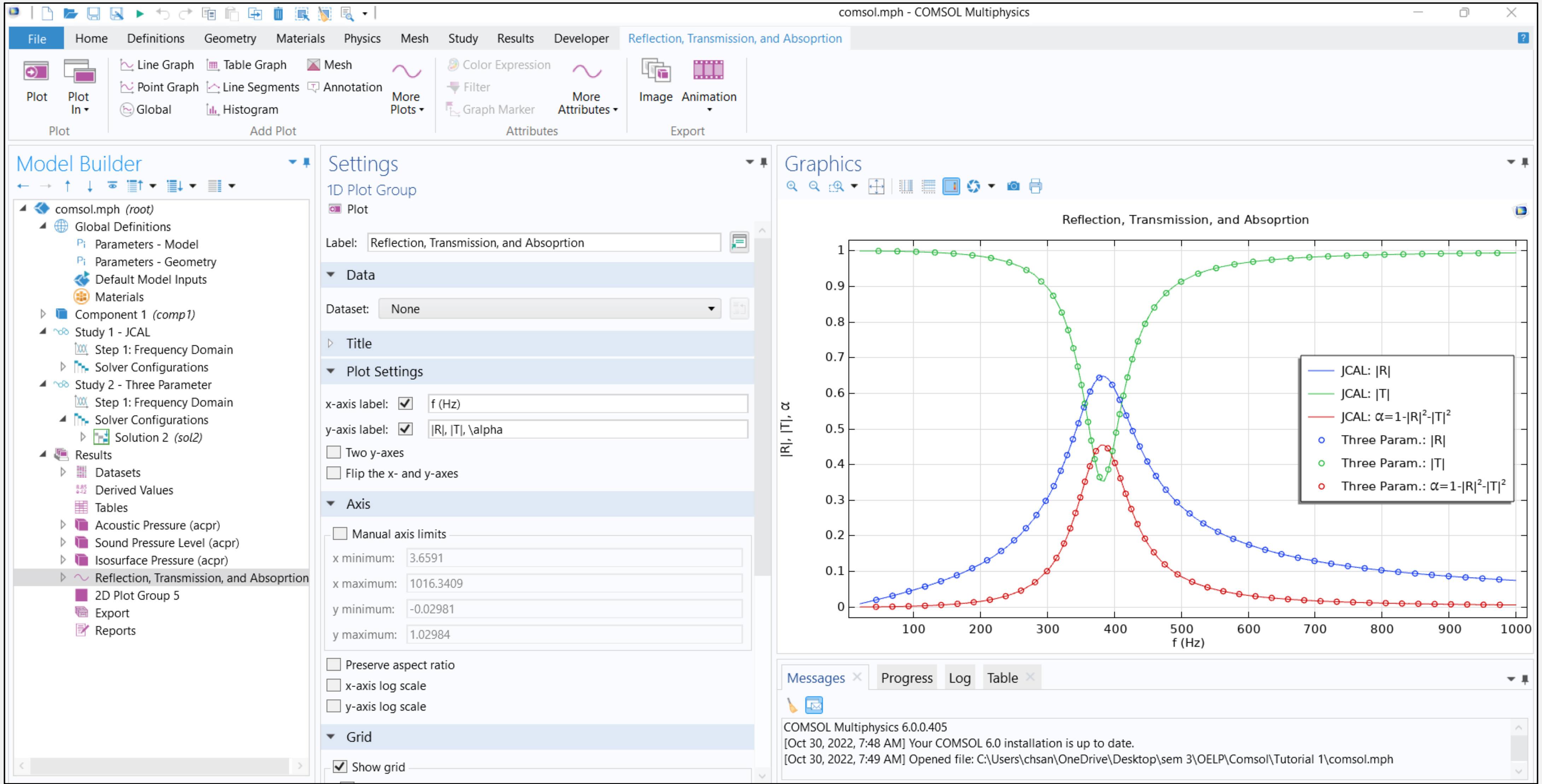
Comsol multiphysics.

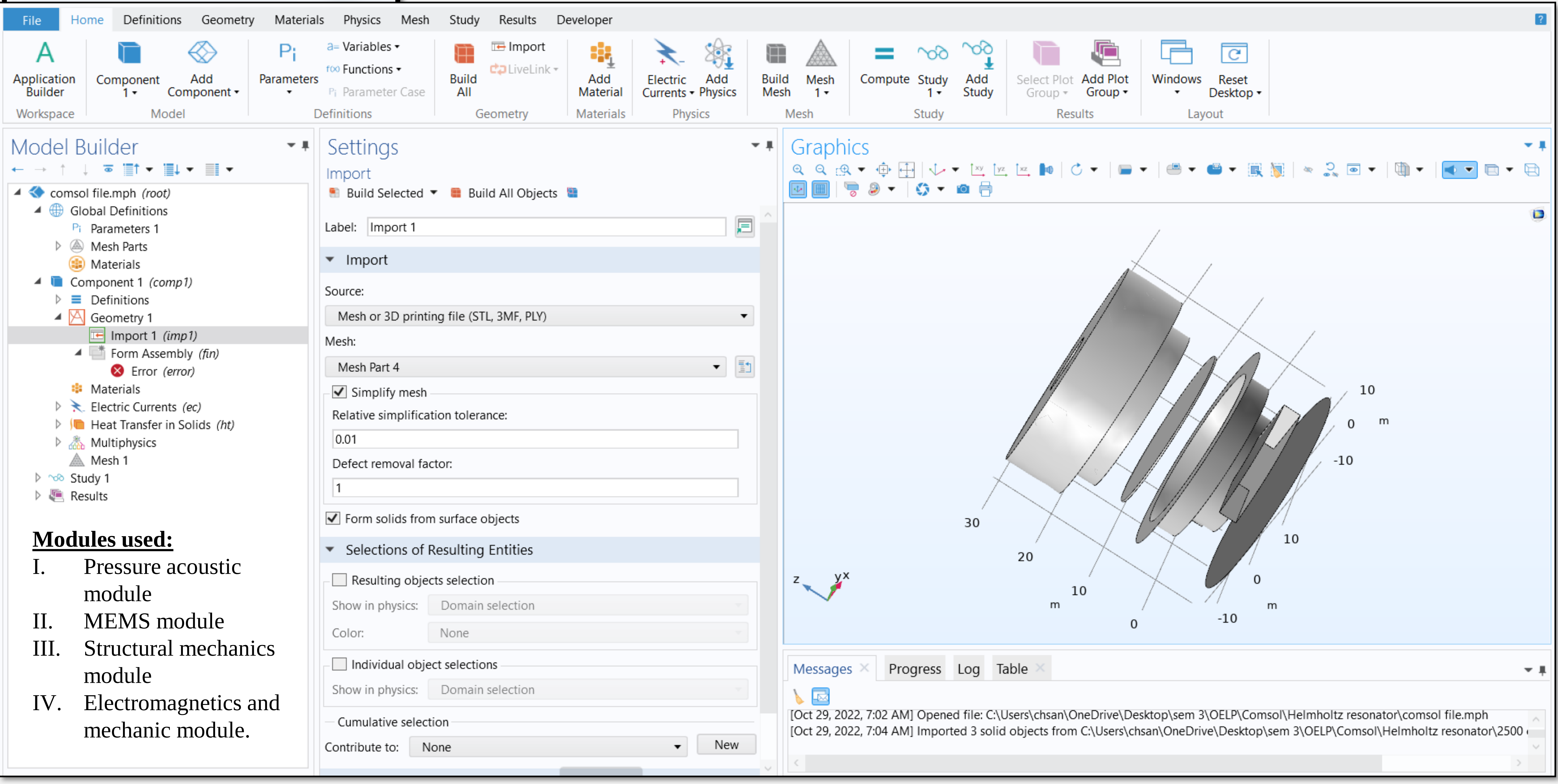
- The below picture is extracted from one of the tutorials given in [comsol mulyiphysics](). The below picture tells us the various iso-pressure surfaces in the duct. Here one disk represents that in the area occupied by that disk is at same total acoustic pressure. Acoustic pressure is maximum at ends and gets minimized s we are moving from ends to center.



Comsol multiphysics.

The above picture is a 2-D representation of reflection, transmission and absorption with frequency. Reflection and absorption are maximum at same frequency (around 380 Hz) and converges to zero as frequency becomes zero and as frequency gets higher and higher. As transmission will be lower whenever reflection and transmission are high, so absorption is minimum at 380 Hz and converges to identity at 0 Hz and higher frequencies.





Modules used:

I. Pressure acoustic module
II. MEMS module
III. Structural mechanics module
IV. Electromagnetics and mechanic module.

THE END

- Done by Sandeep

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