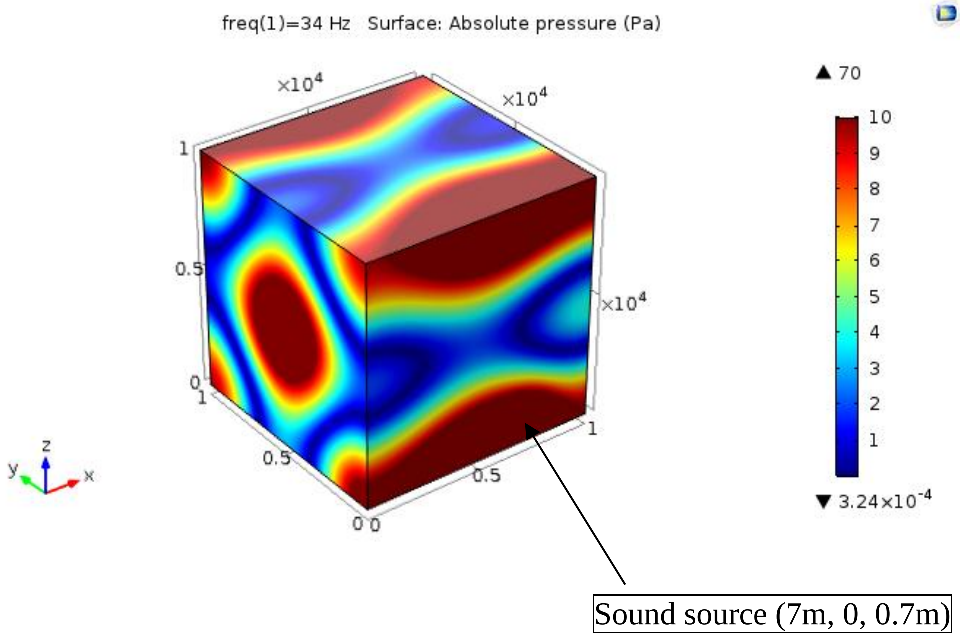
Case: Room mode



Dimensions of the room: 10m×10m ×10m;

Boundary condition: all the 6 surfaces are set as ‘sound hard boundary’.

Sound source: monopole source, volume flow rate Q_s = 0.1 m^3/s.

Frequency for calculation: 34Hz.

The material in the enclosed spaces is air, the density was set as 1.225kg/m^3.

<u>Governing equations for Comsol calculation</u>

$$\frac{1}{\rho c^2}\frac{\partial^2 p}{\partial t^2} + \nabla\left[-\frac{1}{\rho}\left(\nabla p - \boldsymbol{q_d}\right)\right] = Q_m$$

$$Q_m = \frac{4\pi}{\rho} \cdot S \cdot \delta(x - x_0)$$

$$S = e^{i\varphi} \cdot \frac{i\omega\rho_c Q_s}{4\pi}$$

The document in the Comsol shows that, $\mathbf{q_d}$ is the dipole source with unit N/m^3. S is called monopole amplitude, the unit is N/m. And Q_s is named as volume flow rate, the unit is m^3/s.

Meanwhile, I get the following equations from the handbook on page 82.

$$\nabla^2 p - \frac{1}{c^2} \cdot \frac{\partial^2 p}{\partial t^2} = -\rho \cdot \dot{Q_s}(t) \cdot \delta(x - x_0)$$

$$S(t) = \frac{\rho}{4\pi} \frac{d}{dt} Q_s(t)$$

Where, the $S(t)$ is called monopole strength.

Assuming q_d equals to zero and the density is constant, these two sound wave equations are the same.

So, here are my questions:

1. While I put the monopole source as the initial condition, why there is a $\mathbf{q_d}$ in the equation
$$\frac{1}{\rho c^2} \frac{\partial^2 p}{\partial t^2} + \nabla \left[-\frac{1}{\rho} (\nabla p - \boldsymbol{q_d}) \right] = Q_m$$
what does it mean here? And why should $\mathbf{q_d}$ be subtracted?
2. What does φ mean in the equation
$$S = e^{i\varphi} \cdot \frac{i\omega\rho_c Q_s}{4\pi}$$
And what is the difference between $e^{i\varphi}$ and $e^{i(\omega t - kr)}$, which I have seen in many books?

3. Could you please give me some hints or some referred materials on where these equations come from to help me further understand the room mode? Such as when the initial conditions are based on the intensity or the power of the source.