**Semester 2 BSc Hns Physics MJC-2**

**Propagation and Speed of Sound Waves in a Medium**

**1. Introduction to Sound Waves**

**Sound is a form of mechanical wave produced due to vibrations of particles of a medium. Unlike electromagnetic waves, sound cannot travel in vacuum and always requires a material medium such as solids, liquids, or gases.**

**Sound waves transfer energy, not matter. The particles of the medium oscillate about their mean positions while the wave propagates forward.**

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**2. Nature of Sound Waves**

**Sound waves are longitudinal waves, meaning:**

- **Particles vibrate parallel to the direction of wave propagation.**
- **The wave consists of alternate regions of:**
    - **Compressions (high pressure, high density)**
    - **Rarefactions (low pressure, low density)**

**Key Characteristics:**

- **Pressure and density of the medium vary periodically.**
- **Distance between two successive compressions or rarefactions is called wavelength (λ).**

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**3. Propagation of Sound in a Medium**

**The propagation of sound occurs due to the elastic and inertial properties of the medium.**

**Mechanism of Propagation:**

1. **A vibrating source (like a tuning fork) creates a compression in nearby particles.**
2. **These particles push adjacent particles, creating a chain reaction.**
3. **This results in the forward movement of compressions and rarefactions.**

**Important Point:**
**Individual particles only vibrate locally; the disturbance travels, not the particles.**

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**4. Conditions Necessary for Propagation**

**For sound to propagate through a medium, the following properties are essential:**

**(a) Elasticity**

- **Allows the medium to return to its original shape after deformation.**
- **Measured by elastic modulus (Bulk modulus for fluids, Young's modulus for solids).**

**(b) Inertia**

- **Due to mass of particles.**
- **Enables particles to resist changes in motion.**

**A medium lacking either elasticity or inertia cannot transmit sound.**

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**5. Speed of Sound**

**The speed of sound (v) is defined as the distance travelled by the sound wave per unit time.**

**v=vλv = \nu \lambdav=vλ**

**where**

- **v\nuv = frequency**
- **λ\lambdaλ = wavelength**

**The speed of sound depends on the nature of the medium, not on frequency or amplitude (for ordinary conditions).**

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**6. Speed of Sound in Different Media**

**(a) In Solids**

**Sound travels fastest in solids due to high elasticity.**

**v=Yρv = \sqrt{\frac{Y}{\rho}}v=ρY**

**where**

- **YYY = Young's modulus**
- **ρ\rhoρ = density**

**✓ Example: Steel, iron**

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**(b) In Liquids**

**Sound travels slower than in solids but faster than in gases.**

**v=Kρv = \sqrt{\frac{K}{\rho}}v=ρK**

**where**

- **KKK = Bulk modulus**

**✓ Example: Water**

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**(c) In Gases**

**Sound travels slowest in gases.**

**v=γPρv = \sqrt{\frac{\gamma P}{\rho}}v=ργP**

**or**

**v=γRTMv = \sqrt{\frac{\gamma RT}{M}}v=MγRT**

**where**

- **γ\gammaγ = ratio of specific heats**
- **PPP = pressure**
- **TTT = temperature**
- **MMM = molar mass**

**✓ Example: Air**

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**7. Factors Affecting Speed of Sound**

**(a) Effect of Elasticity**

- **Higher elasticity → higher speed**
- **Solids > Liquids > Gases**

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**(b) Effect of Density**

- **Generally, higher density → lower speed (if elasticity is constant)**

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**(c) Effect of Temperature (in gases)**

**v∝Tv \propto \sqrt{T}v∝T**

- **Speed of sound increases with temperature.**
- **In air:**

**$v = 331 + 0.6T \ \text{m/s}$**

**(where $T$ is in °C)**

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**(d) Effect of Humidity**

- **Increase in humidity increases speed of sound in air**
- **Moist air is less dense than dry air**

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**(e) Effect of Pressure**

- **At constant temperature, pressure has no effect on speed of sound in gases.**