Mechanical Wave

Velocity of mechanical wave: $v = \sqrt{\frac{E}{\rho}}$ E = modulus of elasticity of medium

ρ = density of medium

$\left(\frac{E}{\rho}\right)_{solid} > \left(\frac{E}{\rho}\right)_{liquid} > \left(\frac{E}{\rho}\right)_{air}$ Hence, speed of sound is maximum in solid.

Velocity of sound in air: $v = \sqrt{\frac{\gamma P}{\rho}}$ | $v \propto \frac{1}{\sqrt{\rho}}$ | $v = \sqrt{\frac{\gamma RT}{M}}$ | $v \propto \sqrt{T}$

$v = \lambda f$ | $\frac{v_1}{v_2} = \sqrt{\frac{\rho_2}{\rho_1}}$ | $\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$

According to **Newton**, the propagation of sound wave through air is an **isothermal process**. This assumption developed incorrect result. Hence, modification is needed.

According to **Laplace**, the propagation of sound wave through air is an **adiabatic process**. This modification developed correct result.

- ♣ Speed of sound in air is independent of pressure.
- ♣ As we go up in the atmosphere, both density and pressure of air decrease in such a way that the ratio (P/ρ) remains constant. Hence speed of sound will not change.
- ♣ Atomicity of gas: $\gamma = 1.67\ (for\ monoatomic\ gas)$ $\gamma = 1.4\ (for\ diatomic\ gas)$ $\gamma = 1.3\ (for\ triatomic\ gas)$

$since, v \propto \gamma,$ hence, speed of sound is greatest in monoatomic gas.

1. Laplace correction to determine the speed of sound follows:
   a. adiabatic process b. isothermal process c. isochoric process d. isobaric process
2. In which of the following medium, the velocity of sound is highest in
   a. vacuum b. water c. air d. steel
3. Laplace's correction in the expression for the velocity of sound given by Newton is needed because sound waves propagate
   a. longitudinally b. adiabatically c. isothermally d. isobarically
4. Speed of sound is maximum in
   a. monoatomic gas b. diatomic gas c. polyatomic gas d. equal in all

1. a. What are transverse waves? Why are they called as shear wave? 2
   b. Amongst solids, liquids, and gases, in which type of media, transverse wave motion is possible? Why? 2
   c. The sound of an explosion on the surface of a pond is heard by a boatman 50m away and by a sea diver 50m below the point of explosion.
      i. Of the two persons mentioned, who would hear the sound first? Explain. 2
      ii. If the point of explosion was above the surface of the water, who would hear the sound first? Explain. 2
2. a. When sound waves travel through a medium, does the temperature at various points remain constant? 1
   b. Write down relation of Laplace's correction of speed of sound in gaseous medium. 1
   c. Find the atomicity (γ) of the gas at NTP. Density of air at NTP is 1.293kg/m³. 2
   d. Calculate the increase in velocity of sound produced by 1°C rise in temperature, if the velocity of sound at 0°C 332m/s. [**Ans 0.61m/s**] 2
   e. At what temperature will the velocity of sound in air be double than the velocity in air at 22°C? [**1180K**] 2
   f. Write Newton's formula for the speed of sound in the gas. Why and what correction was applied by Laplace in this formula? 2
   g. Discuss the effect of temperature and pressure on the velocity of sound in air. 2
   h. Explain which property of a medium is responsible to form wave patterns from SHM of particles. 2
3. The speed of sound derived from Newton's formula was corrected by Laplace.
   a. What was the correction made by Laplace over Newton's theory? 1
   b. Write the Laplace formula of velocity of sound in air. Discuss the effect of pressure and temperature on the speed of sound in air. 2
   c. At what temperature the velocity of sound is double than at 27^oC? 2
   d. At what temperature, the velocity of sound in air is increased by 50% to that at 27°C? 2

1. The velocity of sound in air at NTP is 330 m/s. What will be its value when temperature is doubled and pressure is halved?
   a. 330 m/s b. 165 m/s c. $330\sqrt{2}$ m/s d. $330/\sqrt{2}$ m/s
2. A man heard the thunder 6 seconds later he saw lightning. The temperature of the air is 27°C. How far was the flash of light from the man? (Velocity of sound in air at 0°C is 332 m/s)
   a. 1822 m b. 2088 m c. 2445 m d. 2332 m
3. Velocity of sound in the air remains unaffected when the wind blows by making
   a. 0^o b. 90^o c. 180^o d. never
4. The velocity of sound in air is independent of changes in
   a. density b. temperature c. pressure d. humidity
5. Young's modulus of steel is $2 \times 10^{11} N/m$ and the density is $78 \times 10^2\ kg/m^3$. The velocity of sound in the steel is
   a. 340 m/s b. 900 m/s c. 4050 m/s d. 5060 m/s

1. a. During a lightning, light and sound are produced simultaneously but we see light before we hear the sound. Why? 2
   b. Using concept in (a), estimate the distance of the lightning strike from the boy. Where, a lightning flash which is followed by a thunder 3 secs later. Given, velocity of sound on that day= $332\ m/s$, velocity of light (c) = 3×10^8 m/s. [**Ans: 996 m**] 3
   c. Hydrogen and oxygen gas are at same temperature. In which medium does the sound travel faster? Explain. 2
   d. A man standing at one end of a closed corridor $57m$ long blew a short blast on a whistle. He found that the blast to the sixth echo was 2 seconds. If the temperature was 17^oC, what was the velocity of sound at 0^oC? [**342m/s, 332m/s**] 2
   e. d. A tuning fork of frequency 220Hz produces sound waves of wavelength 1.5m in air at NTP. Calculate the increase in wavelength when the temperature of the air is 27^oC. [Ans: 8**64.8m**] 2
   f. A fisherman notices that his boat is moving up and down periodically owing to waves on the surface of water. It takes 2.5 sec for the boat to travel from its highest point to its lowest point, a total distance of 62 cm. the fisherman sees that the wave crests are spaced 6m apart.
      i. What is the amplitude of wave?
      ii. How fast are the waves travelling? [$\mathbf{0.31m, 1.2\ m/s}$]