DPP – 1 (Sound Waves)

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Q 1. The speed of sound will be maximum in
(a) Humid air at 25°C (b) Dry air at 25°C
(c) Humid air at 5°C (d) Dry air at 5°C

Q 2. Under the same conditions of pressure and temperature, the velocity of sound in oxygen and hydrogen gases are V_O and V_H then
(a) $V_H = V_O$ (b) $V_H = 4V_O$
(c) $V_H = \frac{V_O}{4}$ (d) $V_H = 16V_O$

Q 3. The speed of sound in gas at NTP is 300 m/s. If the pressure is increased four times without a change in temperature the velocity of sound will be?
(a) 150 m/s (b) 300 m/s
(c) 600 m/s (d) 1200 m/s

Q 4. The frequency of a rod is 200 Hz. If the velocity of sound in air is 340 m/s, the wavelength of the sound produced is
(a) 1.7 cm (b) 6.8 cm
(c) 1.7 m (d) 6.8 m

Q 5. Calculate the speed of longitudinal wave in steel. Young's modulus for steel is 3×10^{10} N/m^2 and its density 1.2×10^3 kg/m^3
(a) 5000 m/s (b) 300 m/s
(c) 3300 m/s (d) 1500 m/s

Q 6. Calculate the speed of longitudinal sound wave in a liquid. The bulk modulus for the liquid is 20×10^9 N/m^2 and its density is 9.5×10^3 kg/m^3
(a) 440 m/s (b) 170 m/s
(c) 1450 m/s (d) 775 m/s

Q 7. For aluminium, the bulk modulus and modulus of rigidity are 7.5×10^{10} N/m^2 and 2.01×10^{10} N/m^2 respectively. Find the velcoity of longitudinal and transverse wave in the medium. Given desity of aluminium is 2.7×10^3 N/m^2.
(a) 6.18×10^3 m/s, 2.7×10^3 m/s
(b) 3.2×10^4 m/s, 2.7×10^3 m/
(c) 6.18×10^3 m/s, 5.1×10^3 m/s
(d) 1.2×10^4 m/s, 3.2×10^4 m/s

Q 8. Laplace's correction in the formula for the speed of sound given by Newton was needed because sound waves

(a) are longitudinal (b) propagate isothermally

(c) propagate adiabatically (d) have long wavelengths

Q 9. The speed of sound in a gas is v and the root mean square speed of gas molecules is v_{rms}. If the ratio of the specific heats of the gas is 1.5 then the ratio $\frac{v}{v_{rms}}$ is

(a) 1 : 2 (b) 1 : $\sqrt{3}$

(c) 1 : $\sqrt{2}$ (d) 1 : 3

Q 10. The temperature at which speed of sound in air becomes double its value at 0 °C is

(a) 546 °C (b) 819 °C

(c) 273 °C (d) 1092 °C

Q 11. The specific gravity of oxygen and nitrogen are in the ration of 16 : 14. The temperature at which the velocity of sound will be the same as that of nitrogen at 15 °C will be:

(a) 112 °C (b) 72 °C

(c) 48 °C (d) 55 °C

Q 12. If the air pressure is doubled at constant temperature, then the speed of sound will be become-

(a) Double (b) Three time

(c) Four time (d) Remain constant

Q 13. Find the speed of sound in a mixture of 1 mole of helium and 2 moles of oxygen at 27 °C.

If the temperature is raised by 1K from 300K, find the percentage change in the speed of sound in the gaseous mixture. [Take R = 8.31 J/mol-K]

(a) 340 m/s, 1.67 % (b) 349.2 m/s, 1.33 %

(c) 200 m/s, 0.67 % (d) 400.9 m/s, 0.167 %

Q 14. The speed of sound in a mixture of $n_1 = 2$ moles of He, $n_2 = 2$ moles of H_2 at temperature T = $\frac{972}{5}$ K is $n \times 10\ m/s$. Find n

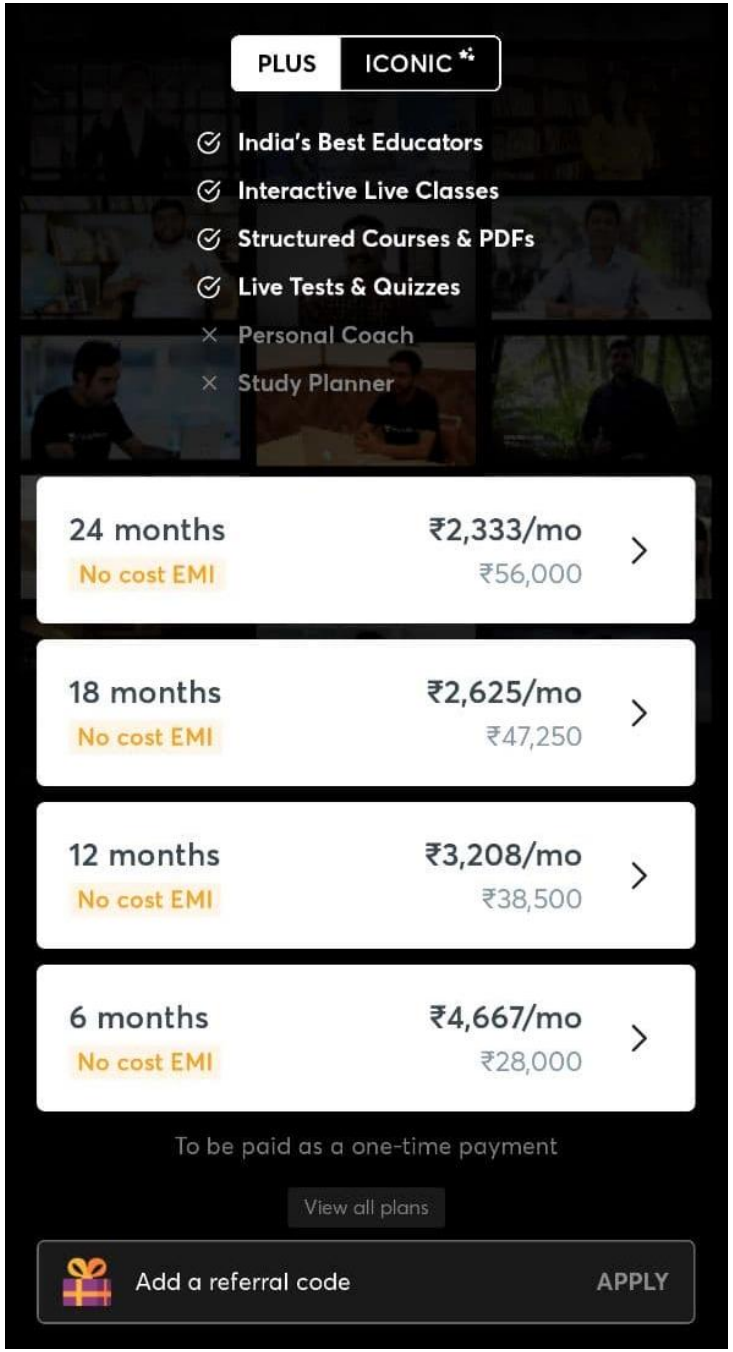
[Take R = $\frac{25}{3}$ J/mol-K]

(a) 9 (b) 90

(c) 15 (d) 35

Answer Key

Q.1 a	Q.2 b	Q.3 b	Q.4 c	Q.5 a
Q.6 c	Q.7 a	Q.8 c	Q.9 c	Q.10 b
Q.11 d	Q.12 d	Q.13 d	Q.14 b	



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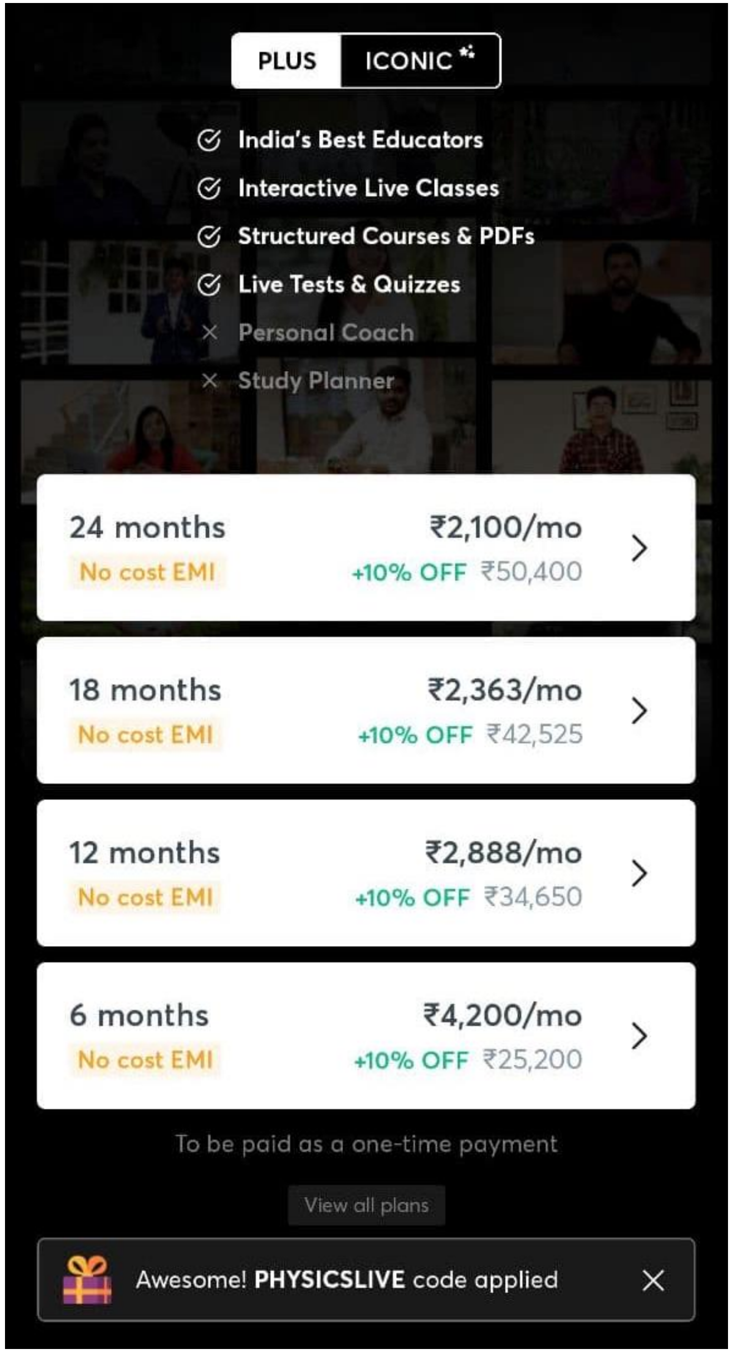

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Written Solution

DPP-1 Sound Waves: Speed of Sound in Fluid, Solid & Gas

By Physicsaholics Team

Solution: 1

v = speed of sound

T = Temperature

d = density of medium

& $v \propto T$ & $v \propto \frac{1}{\sqrt{d}}$

T = 5°C and 25°C

so; $(v)_{T=25°C} > (v)_{T=5°C}$ —(1)

And; as we know that dry air is more dense than Humid air.

$\Rightarrow \rho_{dry} > \rho_{Humid}$

& $v \propto \frac{1}{\sqrt{d}}$

so; $v_{Humid} > v_{dry}$ —(2)

so; combining results from equation 1 & 2

Velocity of Humid air at 25°C is maximum.

Ans. a

Solution: 2

Speed of sound in air $v = \sqrt{\frac{\gamma P}{\rho}}$

$$v = \sqrt{\frac{\gamma RT}{M}}$$

when; P & T = constant

$v \propto \frac{1}{\sqrt{M}}$; M = molecular mass of gas molecules.

so, $\frac{V_H}{V_O} = \sqrt{\frac{M_O}{M_H}}$

$$= \sqrt{\frac{32}{2}} = \frac{\sqrt{16}}{1} = \frac{4}{1}$$

$\boxed{V_H = 4V_O}$ Ans.

Ans. b

Solution: 3

$$v = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}$$

$$v \propto \sqrt{T}$$

as Temperature = Constant

then; v = Constant

so; $\boxed{v = 300\ m/s}$ Ans

Ans. b

Solution: 4

$f = 200\ Hz$

$v = 340\ m/s$

$\because\ v = f\lambda$

$\Rightarrow\ \lambda = \frac{v}{f}$

$\lambda = \frac{340}{200}$

$\boxed{\lambda = 1.7\ m}$ Ans

Ans. c

Solution: 5

$$V = \sqrt{\frac{Y}{\rho}}$$

$$= \sqrt{\frac{3 \times 10^{10}}{1.2 \times 10^{3}}}$$

$$= \sqrt{\frac{3 \times 10^{7}}{1.2}}$$

$$V = \sqrt{\frac{3 \times 10^{8}}{12}} = \sqrt{\frac{10^{8}}{4}}$$

$$V = \frac{10^{4}}{2} = \frac{10000}{2}$$

$$\boxed{V = 5000 \text{ m/s}}$$ Ans.

Ans. a

Solution: 6

$$V = \sqrt{\frac{B}{\rho}}$$

$$V = \sqrt{\frac{20 \times 10^9}{9.5 \times 10^3}}$$

$$V = \sqrt{\frac{20}{9.5} \times 10^6}$$

$$= \sqrt{2.105 \times 10^6}$$

$$V = 1.45 \times 10^3 \text{ m/s}$$

$$\boxed{V = 1450 \text{ m/s}}$$ Ans.

Ans. c

Solution: 7

$B = 7.5 \times 10^{10}\ N/m^2$

$\eta = 2.01 \times 10^{10}\ N/m^2$

$\rho = 2.7 \times 10^{3}\ kg/m^3$

Velocity of longitudinal wave in solids:

$$V_l = \sqrt{\frac{B + \frac{4}{3}\eta}{\rho}}$$

$$V_l = \sqrt{\frac{(7.5 \times 10^{10}) + \frac{4}{3}(2.1 \times 10^{10})}{2.7 \times 10^3}}$$

$$V_l = \sqrt{\frac{10.3 \times 10^{10}}{2.7 \times 10^3}}$$

$$V_l = \sqrt{3.81 \times 10^7} = \sqrt{37.7 \times 10^6}$$

$$\boxed{V_l = 6.17 \times 10^3\ m/s}$$ Ans

Velocity of Transverse wave in solids:

$$V_T = \sqrt{\frac{\eta}{\rho}}$$

$$V_T = \sqrt{\frac{2.1 \times 10^{10}}{2.7 \times 10^3}}$$

$$= \sqrt{\frac{7}{9} \times 10^7}$$

$$= \sqrt{\frac{70}{9} \times 10^6} = \frac{\sqrt{70}}{3} \times 10^3$$

$$\boxed{V_T = 2.7 \times 10^3\ m/s}$$ Ans

Ans. a

Solution: 8

Laplace corrected Newton’s formula by assuming that, there is no heat exchange takes place as the compression and rarefaction takes place very fast. Thus, the temperature does not remain constant and the propagation of the sound wave in air is an adiabatic process.

Ans. c

Solution: 9

$\because \quad V_{rms} = \sqrt{\frac{3RT}{M}}$

and; speed of sound wave $= V = \sqrt{\frac{\gamma RT}{M}}$

so; $\frac{V}{V_{rms}} = \frac{\sqrt{\frac{\gamma RT}{M}}}{\sqrt{\frac{3RT}{M}}}$

$\frac{V}{V_{rms}} = \sqrt{\frac{\gamma}{3}}$

$\frac{V}{V_{rms}} = \sqrt{\frac{1.5}{3}}$

$\boxed{\frac{V}{V_{rms}} = \sqrt{\frac{1}{2}}}$ Ans

Ans. c

Solution: 10

$\because v \propto \sqrt{T}$

at Temp $= T_1 = 0°C = 273\ K$; $v_1 = v$

for Temp $= T_2$; $v_2 = 2v$

so;

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$$

$$\frac{v_1}{2v_1} = \sqrt{\frac{273}{T_2}}$$

$$\left(\frac{1}{2}\right)^2 = \left(\sqrt{\frac{273}{T_2}}\right)^2$$

$$\frac{1}{4} = \frac{273}{T_2}$$

so; $T_2 = 1092\ K$

$$\boxed{T_2 = 1092\ K = 819\ °C}$$ Ans.

Ans. b

Solution: 11

$$V_O = V_N$$

$$\sqrt{\frac{3RT_O}{M_O}} = \sqrt{\frac{3RT_N}{M_N}}$$

$$\Rightarrow \frac{T_O}{M_O} = \frac{T_N}{M_N}$$

$$\Rightarrow \frac{T_O}{32} = \frac{(14+273)}{28}$$

$$\boxed{T_O = 328\text{ K}}$$

$$\boxed{T_O = 55\ ^\circ C}\ \text{Ans}$$

Ans. d

Solution: 12

$$v = \sqrt{\frac{3P}{\rho}}$$

$$\boxed{v = \sqrt{\frac{3RT}{M}}}$$

$$\Rightarrow v \propto \sqrt{T}$$

when; $T = \text{const}$

$$\boxed{v = \text{const}} \quad \text{Ans.}$$

Ans. d

Solution: 13

(a) $n_1 = 1$ mole ; $\gamma_1 = \frac{5}{3}$ [He – monoatomic gas]

$n_2 = 2$ mole ; $\gamma_2 = \frac{7}{5}$ [O_2 – diatomic gas]

$n = n_1 + n_2 = 3$ mole

$$\frac{n}{\gamma_{mix}-1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}$$

$$\frac{3}{\gamma_{mix}-1} = \frac{1}{\frac{5}{3}-1} + \frac{2}{\frac{7}{5}-1}$$

$$\frac{3}{\gamma_{mix}-1} = \frac{3}{2} + 5 = \frac{13}{2}$$

$$\frac{6}{13} = \gamma_{mix} - 1 \Rightarrow \boxed{\gamma_{mix} = \frac{19}{13}}$$

Molecular mass of mixture gas

$$M = \frac{n_1 M_1 + n_2 M_2}{n_1 + n_2} = \frac{(1 \times 4) + 2(32)}{1+2}$$

$$\boxed{M = \frac{68}{3} \text{ gm/mole}}$$

$$v = \sqrt{\frac{\gamma_{mix} R T}{M}} = \sqrt{\frac{\frac{19}{13} \times 8.31 \times 300}{(68/3) \times 10^{-3} \text{ kg}}}$$

$$\boxed{v = 400.9 \text{ m/s}} \text{ Ans}$$

(b) $\because v \propto \sqrt{T} \Rightarrow \frac{\Delta v}{v}\% = \frac{1}{2}\frac{\Delta T}{T}\%$

$$\frac{\Delta v}{v}\% = \frac{1}{2}\left(\frac{1}{300} \times 100\right) = \frac{1}{6}$$

$$\boxed{\frac{\Delta v}{v}\% = 0.167\ \%} \text{ Ans}$$

Ans. d

Solution: 14

$$M = \frac{n_1 M_1 + n_2 M_2}{n_1 + n_2}$$

$$= \frac{(2\times 4) + (2\times 2)}{2+2}$$

$$M = \frac{12}{4}$$

$$\boxed{M = 3 \text{ gm/mole}}$$

for He; $\gamma_1 = \frac{5}{3}$ & $n_1 = 2$ mole

for H_2; $\gamma_2 = \frac{7}{5}$ & $n_2 = 2$ mole

$$\frac{n}{\gamma_{mix}-1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}$$

$$\frac{4}{\gamma_{mix}-1} = \frac{2}{\frac{5}{3}-1} + \frac{2}{\frac{7}{5}-1}$$

$$\frac{4}{\gamma_{mix}-1} = 2\left(\frac{3}{2} + \frac{5}{2}\right) = 2\left(\frac{8}{2}\right)$$

$$\gamma_{mix} - 1 = \frac{1}{2}$$

$$\boxed{\gamma_{mix} = \frac{3}{2}}$$

$$v = \sqrt{\frac{\gamma_{mix} RT}{M}} = \sqrt{\frac{\frac{3}{2} \times \frac{25}{3} \times \frac{972}{5}}{3\times 10^{-3}}}$$

$$v = \sqrt{\frac{5\times 972}{2\times 3} \times 10^3}$$

$$v = \sqrt{810\times 10^3} = \sqrt{81\times 10^4}$$

$$v = 9\times 10^2$$

$$\boxed{v = 900 \text{ m/s}}$$ Ans

Ans. b

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