Q1.

A stretched string has a length of 2.00 m and a mass of 3.40 g. A transverse sinusoidal wave is travelling on this string, and is given by $y\,(x,\,t) = 0.030 \sin (0.75\,x - 126\,t)$, where x and y are in meters, and t is in seconds. What is the magnitude of the tension in this string?

Ans.

$$y = y_m sin(kx - \omega t)$$

$$y_m = 0.03\ m, \qquad k = 0.75 m^{-1}, \qquad \omega = 126 Hz$$

$$v = \sqrt{\frac{\tau}{\mu}}$$

$$\tau = v^2\mu ----(1)$$

$$v = \frac{\omega}{k} = \frac{126}{0.75} = 186\frac{m}{s}$$

$$\mu = \frac{m}{L} = \frac{3.4 \times 10^{-3}}{2} = 1.7 \times 10^{-3}\ kg/m$$

Putting values of v and μ in Eq(1)

$$\tau = (186)^2 \times 1.7 \times 10^{-3} = 47.98\ N \approx 48N$$

Q2.

The average power of a sinusoidal wave on a stretched string is P. If an identical wave is sent simultaneously along the same string in the same direction but with a phase difference of 90^{o} from the first wave, the new average power is

Ans

$$P = \frac{1}{2}\mu v \omega^2 y_m^2$$

$$P' = \frac{1}{2}\mu v \omega^2 {y_m'}^2 ----(1)$$

$$y_m' = 2y_m \cos\left(\frac{\varphi}{2}\right)$$

$$at\ \varphi = 90° \qquad y_m' = \sqrt{2}\, y_m ----(2)$$

Putting Eq(2) into Eq(1) we get:

$$P' = \frac{1}{2}\mu v \omega^2 \left(\sqrt{2}\, y_m\right)^2$$

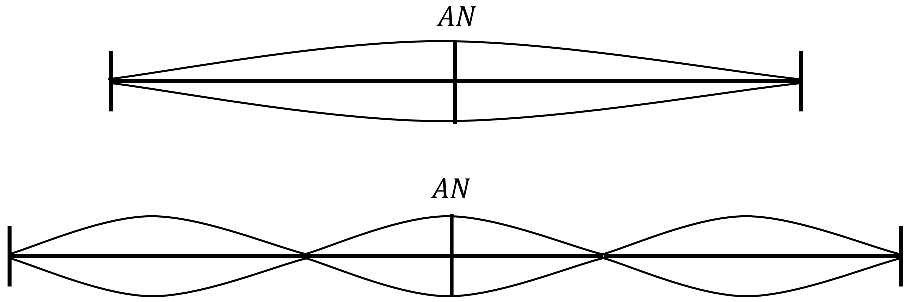
$$P' = 2\left(\frac{1}{2}\mu v \omega^2 y_m^2\right)$$

$$P' = 2P$$

Q3.

For a standing wave on a string fixed at both ends

Ans.



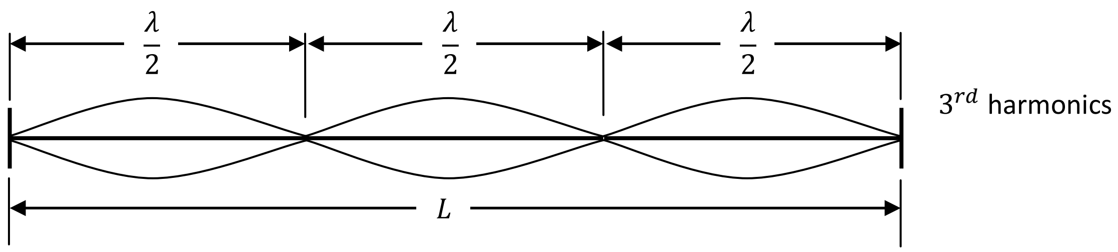
The midpoint is an antinode for odd harmonics.

Q4.

A string that is stretched between fixed supports oscillates in a third-harmonic standing wave pattern. The displacement of the wave is given by $y(x,t) = (0.10)\sin(\pi x/5)\cos(12\pi t)$,

where *x* and *y* are in meters, and *t* is in seconds. What is the length of the string?

Ans



$$L = \frac{3\lambda}{2}$$

From given equation we get:

$$k = \frac{\pi}{5} \Rightarrow \frac{2\pi}{\lambda} = \frac{\pi}{5} \Rightarrow \lambda = 10\ m$$

$$L = \frac{3\lambda}{2} = \frac{3 \times 10}{2} = 15\ m$$

Q5.

A string that is stretched between fixed supports has resonant frequencies of 385 and 430 Hz, with no intermediate resonant frequencies. What is the frequency of the seventh harmonic?

Ans.

$f_n = nf_1 = 385\ Hz$ and $f_{n+1} = (n+1)f_1 = 430\ Hz$

$$f_{n+1} - f_n = (n+1)f_1 - nf_1 = f_1 = 430 - 385 = 45\ Hz$$

The frequency of the seventh harmonic $f_7 = 7\ f_1 = 7 \times 45 = 315\ Hz$

Q6.

If the intensity of a sound wave traveling in air with constant frequency is doubled, then

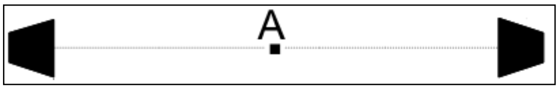
Ans.

Velocity of sound is fixed in given medium; doesn't depend on intensity.

Q7.

Two speakers, separated by 2.00 m, face each other as shown in **Figure 1** . They are driven by the same generator, and emit sound waves with a frequency of 170 Hz, that are initially in phase. A listener is initially at point **A**, which is at the midpoint between the two speakers. What is the shortest distance he should move to find a point of destructive interference? [Take the speed of sound to be 340 m/s]

Fig#1



Maximum intensity at A.

Next minimum will be $(\lambda/4)$ distance away from A

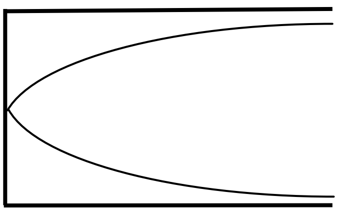
$$d = \frac{\lambda}{4} = \frac{1}{4} \cdot \frac{v}{f} = \frac{1}{4} \cdot \frac{340}{170} = 0.500\ m$$

Q8.

A tube open at both ends has length L_A. A tube open only at one end has length L_B. If the two tubes have the same fundamental frequency, then

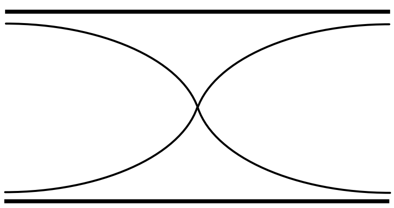
Ans.

Tube B



$$L_B = \frac{\lambda}{4} \Rightarrow \lambda = 4L_B$$

Tube A



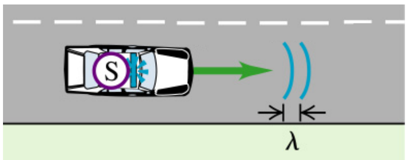
$L_A = \frac{\lambda}{2}$ same fundamental frequency = same fundamental wave length

$$L_A = \frac{4L_B}{2} = 2L_B$$

Q9.

A police car, moving at 20.0 m/s, emits a sound wave with a frequency of 300 Hz. Find the wavelength of the sound wave in front of the car, as shown in **Figure 2**.
[Take the speed of sound in air to be 340 m/s]

Fig#



Ans.

$$\lambda' = \frac{v}{f'} = \frac{340}{f'}$$

$$f' = f\frac{v}{v - v_s} = 300\frac{340}{340 - 20} = 319Hz$$

$$\lambda' = \frac{v}{f'} = \frac{340}{319} = 1.07m$$

Q10.

The melting point of sulfur is 444.6 °C and is 586.1 F° below its boiling point. Determine the boiling point of sulfur in degrees Celsius.

Ans.

$$BP = MP + \Delta C = 444.6 + \Delta C$$

$$\frac{\Delta C}{100} = \frac{\Delta F}{180}$$

$$\Delta C = \frac{100}{180}\Delta F \Longrightarrow \Delta C = \frac{5}{9}\Delta F$$

$$\Delta C = \frac{5}{9} \times 586.1 = 325.6$$

$$BP = MP + \Delta C = 444.6 + 325.6 = 770.2°\text{C}$$

Q11.

An iron tank is completely filled with 2.80 m^3 of water when both the tank and the water are at a temperature of 32.0 °C. When the tank and the water have cooled to 18.0 °C, what additional volume of water can be put into the tank? [α_{iron} = 12.0 × 10^{-6}/ C°, β_{water} = 4.79 × 10^{-4}/ C°]

Ans.

$$\Delta V_I = V_{oI}V_B\Delta T = 2.8 \times 3 \times 12 \times 10^{-6}(18 - 32) = -1.4 \times 10^{-3}\ m^3$$

$$\Delta V_\omega = V_{oI}V_\omega\Delta T = 2.8 \times 4.79 \times 12 \times 10^{-6}(18 - 32) = -18.78 \times 10^{-3}\ m^3$$

$$\Delta V_{odd} = \Delta V_I - \Delta V_\omega = -1.4 \times 10^{-3} + 18.78 \times 10^{-3} = 17.4 \times 10^{-3} m^3$$

Q12.

A 100-g ice cube at 0.0 °C is placed in 650 g of water at 18 °C. If the system is isolated, what is the final temperature?

Ans.

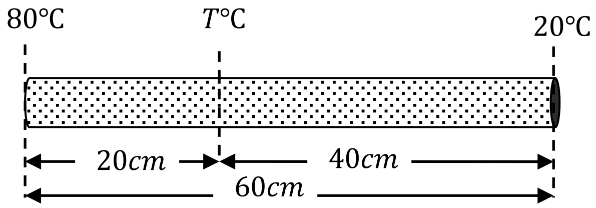
$$m_i L_f + m_i C_\omega (T - 0) = m_\omega C_\omega (18 - T)$$

$$T = \frac{m_\omega C_\omega (18) - m_i L_f}{m_i C_\omega + m_\omega C_\omega} = \frac{0.65 \times 4190 \times 18 - 0.1 \times 333060}{0.65 \times 4190 - 0.1 \times 4190} = 5℃$$

Q13.

A copper rod has a length of 60 cm. One end is maintained at 80 °C and the other end is at 20 °C. In steady state, what is the temperature of the rod at a point which is 20 cm from the hot end? [k_{copper} = 401 W/m.K]

Ans.



$$\frac{KA(80 - T)}{20} = \frac{KA(T - 20)}{40}$$

$$160 - 2T = T - 20$$

$$3T = 180$$

$$T = 60℃$$

Q14.

A 5 moles of an ideal gas expand isobarically from T_i = 25 °C to T_f = 75 °C. Calculate the work done by the gas during this process.

Ans.

$$W = P\Delta V = nR\Delta T = 5 \times 8.31 \times (75 - 25) \approx 2.1 \times 10^3 J$$

Q15.

An ideal gas has a density of 3.75 kg/m^3 and is at a pressure of 1.00 atm. Determine the rms speed of the molecules of this gas.

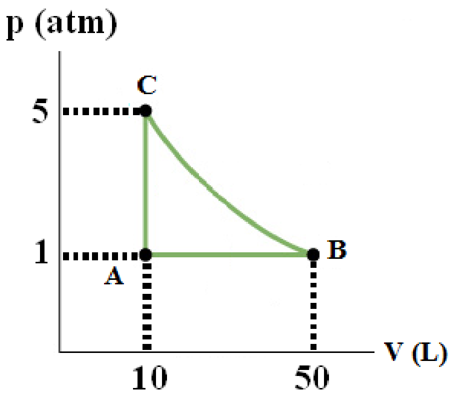
Ans.

$$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3 \times 1.01 \times 10^5}{3.75}} = 28.4 \frac{m}{s}$$

Q16.

An ideal monatomic gas is taken through cycle A→B→C→A, shown in the *p-V* diagram of **Figure 3**, where process B→C is isothermal. Calculate the net work done in one cycle.

Fig#3



Ans.

$$W_{net} = W_{AB} + W_{BC} + W_{CA}$$

$$= P\Delta V + nRT\ln\frac{V_C}{V_B} + 0$$

$$= P(V_B - V_A) + PV\ln\frac{V_C}{V_B}$$

$$= 1.01\times10^5(50\times10^{-3} - 10\times10^{-3}) + 1.01\times10^5\times50\times10^{-3}\times\ln\left(\frac{10\times10^{-3}}{50\times10^{-3}}\right)$$

$$W_{net} = -4088\,J = 4088J, \mathit{on\ the\ gas}.$$

Q17.

One mole of an ideal monatomic gas is initially at a pressure of 1.01×10^5 Pa, a temperature of 300 K, and has a volume of 1.00 L. It is compressed adiabatically to a volume of 0.0667 L. Calculate the magnitude of the work done during this process.

Ans.

$$|W| = \Delta E = \frac{3}{2}nR\Delta T = \frac{3}{2}\times1\times8.31(T_f - T_i)$$

$$T_iV_i^{\gamma-1} = T_fV_f^{\gamma-1} \quad\Rightarrow\quad T_f = T_i\left(\frac{V_i}{V_f}\right)^{\gamma-1} = 300\left(\frac{1}{0.0667}\right)^{\frac{5}{3}-1}$$

$$|W| = \frac{3}{2}\times1\times8.31\times\left[300\left(\frac{1}{0.0667}\right)^{\frac{5}{3}-1} - 300\right] \approx 19\text{KJ}$$

Q18.

A system consists of two large thermal reservoirs in contact with each other, one at a temperature of 300 °C and the other at a temperature 200 °C. If 600 J of heat is transferred from the 300 °C reservoir to the 200 °C reservoir, what is the change in entropy of this system?

Ans.

$$\Delta S = S_2 - S_1 = \frac{Q}{T_2} - \frac{Q}{T_1} = \frac{600}{200+273} - \frac{600}{300+273} = 0.221 \text{ J/K}$$

Q19.

A Carnot refrigerator is operated between two heat reservoirs at temperatures of 320 K and 270 K. In each cycle, the refrigerator extracts 415 J of heat from the cold reservoir. If the refrigerator completes 165 cycles each minute, what is the power input required to operate it?

Ans.

$$P = \frac{W}{t} = \frac{W}{60}$$

$$K = \frac{Q_L}{W} \Longrightarrow \frac{T_L}{T_H - T_L} = \frac{Q_L}{W}$$

$$W = \frac{Q_L(T_H - T_L)}{T_L} = \frac{165 \times 415(320 - 270)}{270}$$

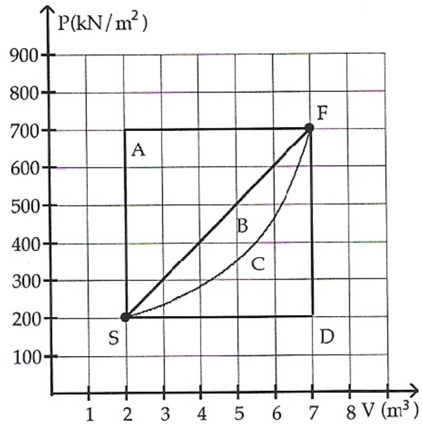
$$P = \frac{W}{t} = \frac{165 \times 415(320 - 270)}{270 \times 60} = 211\, watt$$

Q20.

Which of the processes on an ideal gas shown in **Figure 4** results in the minimum change in entropy of the gas in changing the gas from state S to State F?

Ans.

Fig#4



Entropy is a state function and only depends on the initial and final positions not in the path.