Q1.

If you setup the fifth harmonic on a string clamped at both ends, is there a node, antinode or some intermediate state at the midpoint of the string?

A) Antinode
B) Node
C) Intermediate state
D) None of the others
E) Not enough information given

Ans:

A

Q2.

A string of 80 cm length is fixed at both ends. The string oscillates in the fundamental mode with a frequency of 60 Hz and a maximum amplitude of 0.3 cm of the standing wave. What is the maximum transverse speed of a particle oscillating on the string at x=20 cm?

A) 80 cm/s
B) 71 cm/s
C) 66 cm/s
D) 99 cm/s
E) 91 cm/s

Ans:

$$|u_{max}| = |2\omega y_m sinkx| = |\omega \cdot 2y_m \cdot sinkx|$$

$$\lambda = 2 \times 0.8 = 1.6\, m$$

$$\omega = 2\pi f = 2\pi \times 60 = 120\pi$$

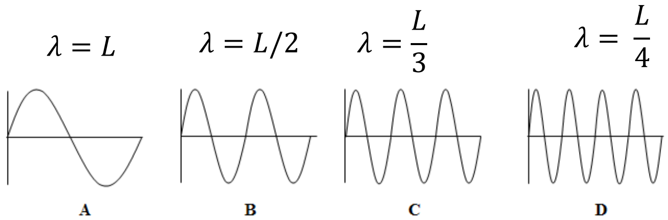
$$|u_{max}| = 120\pi \times 0.3 \times sin\left(\frac{2\pi}{1.6} \times 0.2\right)$$

$$= 120\pi \times 0.3 \times sin(45) = 0.80 m/s = 80 cm/s$$

Q3.

A string fixed at both ends can be made to vibrate in one of the four patterns shown in **FIGURE 1** by varying the tension in the string. Arrange the four patterns in terms of the average power transported by the wave in the string, **smallest first**. The frequency and amplitude of the waves are the same in all the figures.

Figure 1



A) D, C, B, A
B) A, C, B, D
C) B, C, D, A
D) C, B, A, D
E) D, C, A, B

Ans:

$$P = \frac{1}{2}\mu v \omega^2 y_m^2 = \frac{1}{2}\mu\lambda f \cdot (2\pi f)^2 \cdot y_m^2$$

$$= \frac{1}{2} 4\pi^2 f_x^3 y_m^2 x\lambda \Rightarrow P \propto \lambda$$

Q4.

The displacement of a string carrying a traveling sinusoidal wave is given by $y(x,t) = y_m \sin(kx - \omega t + \varphi)$, where x is in meters and t is in seconds.
At time $t = 0$ a particle at $x = 0$ has transverse speed u_0 and displacement y_0. Then magnitude of $tan\phi$ is equal to:

A) $\omega y_0 / u_0$
B) $u_0 / \omega y_0$
C) $\omega u_0 / y_0$
D) $y_0 / \omega u_0$
E) $\omega u_0 y_0$

Ans:

$$y(x,t) = y_m \sin(kx - \omega t + \phi)\,;\, u(x,t) = -\omega y_m \cos(kx - \omega t + \phi)$$

$$\text{at } t = 0, x = 0$$

$$y_0 = y_m\, sin(\phi)\,;\; u_0 = -\omega y_m\, cos(\phi)$$

$$tan(\phi) = \frac{sin(\phi)}{cos(\phi)} = \frac{y_0/y_m}{u_0/\omega y_m} = -\frac{y_0\omega}{u_0}$$

$$|tan(\phi)| = \frac{y_0\omega}{u_0}$$

Q5.

A sound meter placed 3.0 m from a point sound source registers a sound level of 80 dB. What sound level will the sound meter register if the power of the source is reduced by a factor of 25?

A) 66 dB
B) 11 dB
C) 32 dB
D) 3.2 dB
E) 55 dB

Ans:

$$\frac{P_f}{P_i} = \frac{I_f}{I_i} = \frac{1}{25}$$

$$\Delta\beta = 10 \log\left(\frac{I_f}{I_i}\right) = 10 \log\left(\frac{1}{25}\right) = -13.97$$

$$\beta_f = \beta_i + \Delta\beta = 80 - 13.97 = 66.03 \text{ dB}$$

Q6.

A pipe of length L, closed at one end, is resonating at its fundamental frequency. Which one of the following statements is **TRUE**?

A) The wavelength is 4L and there is a displacement antinode at the pipe's open end
B) The wavelength is 4L and there is a displacement node at the pipe's open end
C) The wavelength is 2L and there is a displacement node at the pipe's open end
D) The wavelength is 2L and there is a displacement antinode at the pipe's open end
E) The wavelength is L and there is a displacement antinode at the pipe's open end

Ans:

A

Q7.

Two loudspeakers S_1 and S_2 are in phase and emit sound waves with the same frequency. They are placed along the y-axis and are separated by a distance of 8.00 m, as shown in **FIGURE 2**. A person is standing at point O which is 12.0 m from the y-axis and equidistant from the loudspeakers. When the person moves from point O to point P at a distance of 3 m, he detects the second destructive interference in sound intensity. What is the frequency of the sound waves emitted by the loudspeakers? The speed of sound in air is 343 m/s.

A) 278 Hz
B) 178 Hz
C) 222 Hz
D) 335 Hz
E) 522 Hz

Figure 2

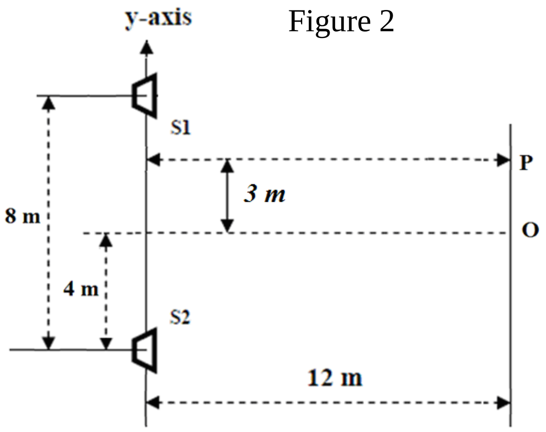


FIGURE NOT TO SCALE

Ans:

$$L_2 = \sqrt{12^2 + 7^2} = 13.89 \text{ m}$$

$$L_1 = \sqrt{12^2 + 1^2} = 12.01 \text{ m}$$

$$\Delta L = 13.89 - 12.01 = 1.849 \text{ m}$$

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

$$\lambda = \frac{2\Delta L}{3} = \frac{2 \times 1.849}{3} = 1.23 \text{ m}$$

$$f = \frac{v}{\lambda} = \frac{343}{1.23} = 278 \text{ Hz}$$

Q8.

A bat emits sound at a frequency of 3.00×10^4 Hz as it approaches a wall. The frequency of the sound reflected from the wall and detected by the bat is 3.09×10^4 Hz. What is the speed of the bat? The speed of sound in air is 343 m/s.

A) 5.07 m/s
B) 3.50 m/s
C) 2.20 m/s
D) 6.30 m/s
E) 7.70 m/s

Ans:

$$f'' = f_o\left(\frac{v + v_{bat}}{v - v_{bat}}\right)$$

$$\frac{f''}{f'} = \frac{3.09 \times 10^4}{3 \times 10^4} = 1.03 = \frac{v + v_{bat}}{v - v_{bat}}$$

$$1.03\,(v - v_{bat}) = v + v_{bat} \Rightarrow 0.03\,v = 2.03\,v_{bat}$$

$$v_{bat} = \frac{0.03 \times v}{2.03} = \frac{0.03 \times 343}{2.03} = 5.07\ m/s$$

Q9.

Materials A, B, and C are solids that are at their melting temperatures. Material A requires 200 J to melt 4 kg, material B requires 300 J to melt 5 kg, and material C requires 300 J to melt 6 kg. Rank the materials according to their heats of fusion, **greatest first**.

A) B, then A and C tie
B) A, then B and C tie
C) C, then A and B tie
D) A, B and C all tie
E) None of the others

Ans:

$$L_{F-A} = \frac{200}{4} = \frac{50\,\text{J}}{kg};\ L_{F-B} = \frac{300}{5} = \frac{60\,\text{J}}{kg};\ L_{F-C} = \frac{300}{6} = 50\,\text{J}/kg$$

Q10.

What is the volume of a lead ball at 10.0 °C if the ball's volume at 260 °C is 97.0 cm^3? (Coefficient of linear expansion of lead $\alpha_{Pb} = 29.0 \times 10^{-6}$ /°C)?

A) 94.9 cm^3
B) 96.1 cm^3
C) 95.5 cm^3
D) 92.1 cm^3
E) 93.5 cm^3

Ans:

$$\Delta V = V_o \beta\, \Delta T = V_o 3\alpha\, \Delta T = 97 \times 3 \times 29 \times 10^{-6} \times (-250) = -2.1097\ \text{cm}^3$$

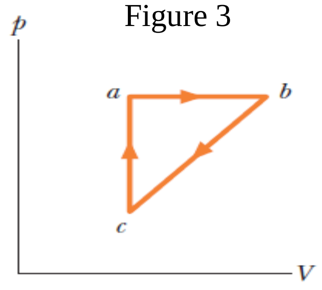
$$V = V_o + \Delta V = 97 - 2.1097 = 94.89\ \text{cm}^3$$

Q11.

The net work done by a gas, when taken through cycle ***abca***, as shown in the p-V diagram of **FIGURE 3** is +2.1 J. Along path ***ab***, the change in the internal energy is +3.2 J and the magnitude of the work done is 5.9 J. Along path ***ca***, the energy transferred to the gas as heat is +1.6 J. What is change in the internal energy and how much energy is transferred as heat along path ***bc***?

A) −4.8 J and −8.6 J
B) −2.5 J and −5.1 J
C) +8.0 J and +7.5 J
D) +5.5 J and +4.3 J
E) −8.0 J and −9.0 J

Figure 3



Ans:

$$Q_{abca} = W = 2.1\ \text{J} = Q_{ab} + Q_{bc} + Q_{ca}$$

$$\boldsymbol{Q_{bc}} = Q_{abca} - Q_{ab} - Q_{ca};\ \ Q_{ab} = \Delta E_m + W = 3.2 + 5.9 = 9.1\ \text{J}$$

$$Q_{bc} = 2.1 - 9.1 - 1.6 = -8.6\ \text{J}$$

$$\Delta E_{in_{abca}} = 0 = \Delta E_{in_{ab}} + \Delta E_{in_{bc}} + \Delta E_{in_{ca}}$$

$$\Delta E_{in_{ab}} = 3.2\ \text{J}, \Delta E_{in_{ca}} = Q_{ca} = 1.6$$

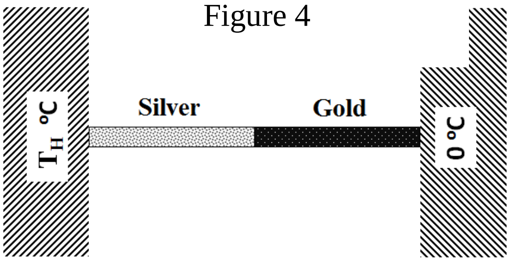
$$\boldsymbol{\Delta E_{in_{bc}}} = -\Delta E_{in_{ab}} - \Delta E_{in_{ca}} = -3.2 - 1.6 = -4.8\ \text{J}$$

Q12.

Two metal cylindrical rods, one gold and the other silver, are welded end-to-end and placed between two heat reservoirs at 0.00°C and T_H °C temperatures, as shown in **FIGURE 4**. Each rod is 5.00 cm long and has a cross sectional area of 4.00 cm^2. What is the temperature T_H of the hot reservoir if, in the steady state, 8.20 kJ of heat flows through the two rods in 60.0 seconds? (Thermal conductivities: k_{Silver} = 417 W/m.K, k_{Gold} = 219 W/m.K)

A) 119°C
B) 103°C
C) 100°C
D) 127°C
E) 135°C

Figure 4



Ans:

$$P_{cm} = \frac{Q}{t} = \frac{8.2 \times 10^3}{60} = 136.7\ \mathrm{W}$$

$$P = \frac{A(T_H - T_C)}{L\left(\frac{1}{k_{silver}} + \frac{1}{k_{gold}}\right)} \Rightarrow T_H - T_C = \frac{P \times L}{A}\left(\frac{1}{k_{silver}} + \frac{1}{k_{gold}}\right)$$

$$T_H - T_C = \frac{136.7 + 5 \times 10^{-2}}{4 \times 10^{-4}}\left(\frac{1}{417} + \frac{1}{219}\right) = 119.00$$

$$T_H = T_C + 119 = 0 + 119℃ = 119℃$$

Q13.

A certain amount of an ideal gas absorbs 30 J of heat at constant volume when its temperature increases by ΔT C°. When the same gas is heated at constant pressure it absorbs 50 J of heat for the same ΔT C°. How much work is done by the gas in the constant pressure process?

A) 20 J
B) 33 J
C) 50 J
D) 15 J
E) 10 J

Ans:

At constant P

$$\Delta E_{in} = Q_p - W_p; \Delta E_{in} = nC_v\Delta T = Q_v$$

$$Q_v = Q_p - W_p$$
$$W_p = Q_p - Q_v = 50 - 30 = 20\ \mathrm{J}$$

Q14.

What is the percentage decrease in v_{rms} of the molecules of an ideal hydrogen gas if its temperature is reduced from 100°C to 20°C?

A) 11%
B) 7 %
C) 3 %
D) 15%
E) 14%

Ans:

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{v_f}{v_i} = \sqrt{\frac{T_f}{T_i}} \Rightarrow v_f = v_i\sqrt{\frac{T_f}{T_i}} = v_i\sqrt{\frac{293}{373}} = v_i \times 0.89$$

$$\%\ \text{increase} = \left|\frac{v_f - v_i}{v_i}\right| \times 100 = \left|\frac{0.89v_i - v_i}{v_i}\right| \times 100 = 11\%$$

Q15.

If W is the magnitude of work done on an ideal diatomic gas in an adiabatic process, then the change in translational kinetic energy of the gas molecules is:

A) 3W/5 J
B) 2W/5 J
C) 5W/2 J
D) 0 J
E) W J

Ans:

A; For any ideal diatomic gas

$$|W_{adia}| = |\Delta E_{int}| = nC_v\Delta T = \frac{5}{2}\, nR\Delta T$$

$$nR\Delta T = \frac{2|W_{adia}|}{5}$$

$$\Delta K_{trans} = \frac{3}{2}nR\Delta T = \Delta K_{trans} = \times\frac{2}{5}|W_{adia}|$$

$$\Delta K_{trans} = \frac{3}{5}W$$

Q16.

An ideal diatomic gas occupies a volume of 3.50 L at a pressure of 1.20 atm and a temperature of 300 K. It is compressed adiabatically to a volume of 0.55 L. What is the magnitude of work done in this adiabatic process?

A) 1.16 kJ
B) 0.25 kJ
C) 2.10 kJ
D) 3.61 kJ
E) 1.00 kJ

Ans:

$$|W_{adia}| = nC_v\Delta T = nC_v(T_f - T_i)$$

$$n = \frac{PV}{RT} = \frac{1.2 \times 1.0 \times 10^5 \times 3.5 \times 10^{-3}}{8.314 \times 300} = 0.17 \text{ moles}$$

$$T_f = T_i\left(\frac{V_i}{V_f}\right)^{\gamma-1} = 300\left(\frac{3.50}{0.55}\right)^{0.4} = 629 \text{ K}$$

$$|W_{adia}| = nC_v\Delta T$$

$$|W_{adia}| = 0.17 \times \frac{5}{2} \times 8.314 \times (629 - 300) = 1.16 \times 10^3 \text{ J}$$

Q17.

What will happen to the entropy of an ideal gas that expands in an isothermal process?

A) It will increase.
B) It will decrease.
C) It will remain unchanged.
D) Need more information to answer.
E) Entropy change is not defined for an isothermal process.

Ans:

A

Q18.

The change in entropy of 20.0 moles of an ideal monatomic gas in a constant volume process is 200 J/K. If the initial temperature of the gas was 300 K, what is its final temperature?

A) 669 K
B) 562 K
C) 427 K
D) 187 K
E) 345 K

Ans:

At constant volume $V_f = V_i$

$$\Delta S = nC_v ln\left(\frac{T_f}{T_i}\right) \Rightarrow \frac{T_f}{T_i} = e^{\frac{\Delta S}{nC_v}}$$

$$T_f = T_i e^{\frac{\Delta S}{nC_v}} = 300e^{\frac{200}{20\times\frac{5}{2}\times 8.314}} = 668.9 \text{ K}$$

Q19.

A Carnot engine whose hot reservoir temperature is 400°C has a thermal efficiency of 40 %. By how many degrees should we lower the temperature of the cold reservoir to increase the engine efficiency to 60%?

A) 135°C
B) 105°C
C) 215°C
D) 119°C
E) 171°C

Ans:

$$\varepsilon_c = \frac{T_H - T_L}{T_H} \Rightarrow T_L = T_H(1 - \varepsilon_c) = 673(1 - 0.4) = 403.8 \text{ K}$$

New lower temperature T_L for $\varepsilon_c = 0.6$

$$T_L' = 673\ (1 - 0.6) = 269.2$$

$$\Delta T_L = T_L - T_L' = 403.8 - 269.2 = 134.6 \text{ C}$$

Q20.

The operating temperature of a Carnot refrigerator is 2.0°C. The refrigerator is placed in a kitchen where the temperature is 22°C. What power is needed to operate this refrigerator in order to extract from it 89 MJ of heat in one hour?

A) 1.8 kW
B) 2.0 kW
C) 1.5 kW
D) 2.9 kW
E) 1.0 kW

Ans:

$$Q_L = \frac{Q}{t} = \frac{89 \times 10^6}{60 \times 60} = 24722.2 \text{ J/S}$$

$$\kappa = \frac{Q_L}{W} \Rightarrow W = \frac{Q_L}{K} = \frac{24722.2}{13.758} = 1797.7 \text{ J/S} = 1.8 \text{ kW}$$
