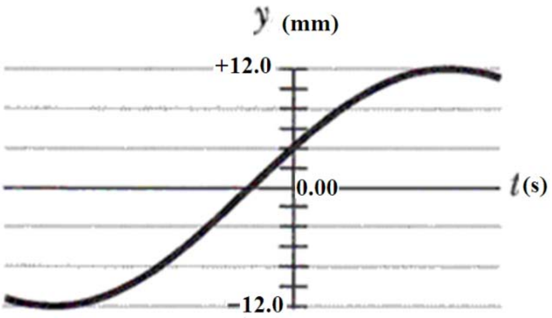
1.

Figure 1 shows the displacement **y** versus time **t**(s) of the point on a string at **x = 0**, as a wave passes through that point. The wave has the form : $y(x,t) = y_m \sin[(3.35m^{-1})x-(15.0s^{-1})t+\Phi]$. What is the wave speed and phase constant Φ, respectively?

A) 4.48 m/s, 19.5^0
B) 7.21 m/s, 14.5^0
C) 4.48 m/s, 4.78^0
D) 7.21 m/s, 19.5^0
E) 4.48 m/s, 43.5^0

Figure # 1



Ans:

$$y(x,t) = 12\,mm\,\sin[(3.35\,m^{-1})x - (15.0\,s^{-1})t + \phi]$$

$$for\ x = 0, t = 0, y(0,0) = 4\,mm$$

$$y(0,0) = 4 = 12\,sin(\phi)$$

$$\phi = \sin^{-1}\left(\frac{4}{12}\right) = 19.5°$$

$$v = \frac{\omega}{k} = \frac{15}{3.35} = 4.48\,m/s$$

Q2.

A 1.00 m long string of mass 10.0 g is subjected to a tension of 25 N. How much average power is required to set up travelling waves in the string of amplitude of 5.00 cm and a frequency of 50.0 Hz?

A) 61.7 W
B) 111 W
C) 91.2 W
D) 30.9 W
E) 15.0 W

Ans:

$$P = \frac{1}{2}\mu v \omega^2 y_m^2\ ;\ \mu = \frac{10^{-3} \times 10}{1} = 10^{-2}\,kg/m$$

$$Then\ v = \sqrt{\frac{\tau}{\mu}} = \sqrt{\frac{25}{0.01}} = 50\,m/s$$

$$P = \frac{1}{2} \times 10^{-2} \times 50 \times (2\pi \times 50)^2 \times (5 \times 10^{-2})^2 = 61.7\text{ W}$$

Q3.

Three transverse waves traveling on separate strings have following wave equations.

$y_1(x, t) = (2.0\text{mm}) \sin[(4.0\ \text{m}^{-1})x - (3.0\ \text{s}^{-1})t]$

$y_2(x, t) = (1.0\text{mm}) \sin[(8.0\ \text{m}^{-1})x - (4.0\ \text{s}^{-1})t]$

$y_3(x, t) = (1.0\text{mm}) \sin[(4.0\ \text{m}^{-1})x - (8.0\ \text{s}^{-1})t]$

Rank them according to the magnitude of maximum transverse acceleration**, least to greatest.**

A) y_2, y_1, y_3
B) y_1, y_2, y_3
C) y_1, y_3, y_2
D) y_3, y_1, y_2
E) y_2, y_3, y_1

Ans:

$|a_{max}| = y_m\omega^2,$

for $y_1 = |a_{1max}| = y_m\omega_1^2 = 2 \times 10^{-3} \times 9 = 18 \times 10^{-3}\ mm/s^2$

for $y_2 = |a_{2max}| = y_{2m}\omega_2^2 = 1 \times 10^{-3} \times 16 = 16 \times 10^{-3}\ mm/s^2$

for $y_3 = |a_{3max}| = y_{3m}\omega_3^2 = 1 \times 10^{-3} \times 64 = 64 \times 10^{-3}\ mm/s^2$

Q4.

A tuning fork of 500 Hz frequency sets up standing waves in a string clamped at both ends. The speed of the waves in the string is 200 m/s. The standing wave has four loops and amplitude of 2.00 mm. Calculate the length of the string.

A) 0.800 m
B) 0.420 m
C) 2.66 m
D) 1.20 m
E) 1. 81 m

Ans:

$$f_n = \frac{nv}{2L}\ ; n = 4, v = 200\ m/s$$

$$L = \frac{nv}{2f_n} = \frac{4 \times 200}{2 \times 500} = 0.800\ \text{m}$$

Q5.

A point sound source, emitting sound waves isotropically with constant power, is located at a distance *d* from you. If you move the source to position at a distance of *2d* from you, by how many decibel (dB) the sound intensity level will drop at your position?

A) 6
B) 4
C) 2
D) 8
E) 10

Ans:

$$I = \frac{P}{4\pi R^2} \Rightarrow I_1 = \frac{P}{4\pi R_1^2}\ ;\ I_2 = \frac{P}{4\pi (2R_1)^2} = \frac{1}{4}\frac{P}{4\pi R_1^2} = \frac{1}{4}\ I_1$$

$$\frac{I_2}{I_1} = \frac{\frac{1}{4}\ I_1}{I_1} = \frac{1}{4}$$

$$\Delta\beta = \beta_2 - \beta_1 = 10\ log(I_2) - 10 log(I_1) = 10 log\left(\frac{I_2}{I_1}\right) = 6$$

Q6.

Organ pipe A, with one open end, has a fundamental frequency of 220 Hz. The next-highest harmonic of pipe A has the same frequency as the third harmonic of a pipe B which has both ends open. How long is pipe B? The speed of sound = 345 m/s.

A) 0.784 m
B) 0.321 m
C) 0.732 m
D) 0.214 m
E) 0.136 m

Ans:

For pipe A $\quad f_{nA} = \dfrac{mv}{4L}\ (m = 1, 3, 5)$

For pipe B $\quad f_{nB} = \dfrac{nv}{2L}\ (n = 1,2, \ldots)$

$$f_{3A} = f_{3B} \Rightarrow f_{3A} = 3f_{1A} = 3 \times 220 = 660\ Hz$$

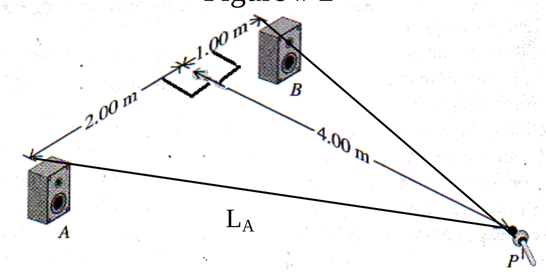
$$f_{3B} = 660 = \frac{3v}{2L_B} \Rightarrow L_B = \frac{3v}{2 \times f_{3B}} = \frac{3 \times 345}{2 \times 660} = 0.784\text{ m}$$

Q7.

Two small speakers, A and B, are driven by the same amplifier and emit pure sinusoidal waves in phase as shown in **Figure 2**. What is the first frequency at which destructive interference occurs and the first frequency at which constructive interference occurs at point P, respectively? Speed of sound = 350 m/s.

A) 500 Hz, 1000 Hz
B) 500 Hz, 1500 Hz
C) 1500 Hz, 500 Hz
D) 1000 Hz, 500 Hz
E) 1000 Hz, 1500 Hz

Figure # 2



Ans:

For a maxima, $\Delta L_{max} = n\lambda$ and for a minima, $\Delta L_{min} = \left(n + \frac{1}{2}\right)\lambda$ for (n = 0,1,2,3, ...)

$$L_A = \sqrt{2^2 + 4^2} = 4.472 \text{ m}$$

$$L_B = \sqrt{1^2 + 4^2} = 4.123\text{m}$$

$$\Delta L = L_A - L_B$$

$$\Delta L = 4.472 - 4.123 = 0.35 \text{ m}$$

$$\lambda_{max} = \Delta L = 0.35;\ f_{max} = \frac{v}{\lambda_{max}} = \frac{350}{0.350} = 1000 \text{ Hz}$$

$$\lambda_{min} = 2\Delta L = 2 \times 0.35 = 0.70\ m;\ f_{min} = \frac{v}{\lambda_{min}} = \frac{350}{0.70} = 500 \text{ Hz}$$

Q8.

Two trains, A and B, are travelling away from each other. Train A, moving at 55.00 m/s relative to the ground, blows a whistle at 1000 Hz frequency. If the frequency of the whistle heard at the train B is 747.0 Hz, what is speed of train B relative to ground? Take the speed of sound to be 340.0 m/s.

A) 45.00 m/s
B) 51.21 m/s
C) 32.76 m/s
D) 27.00 m/s
E) 63.13 m/s

Ans:

$$f' = f_o\left(\frac{v + v_D}{v - v_s}\right) \Rightarrow \frac{f'}{f_o}(v + v_s) = v - v_D$$

$$\frac{f'}{f_o}(v + v_s) = \frac{747}{1000}(340 + 55) = 340 - v_D \Rightarrow 0.74 \times 395 = 340 - v_D$$

$$340 - v_D = 0.74 \times 395 = 295.1$$

$$v_D = 340 - 295.1 = 44.9\ m/s$$

Q9.

What is the change in area (in cm^2) of a 60.0 cm × 150 cm (width × height) glass plate when its temperature increases by 65.0 F°.The coefficient of volume expansion of glass is 2.70×10^{-5} /C°.

A) 5.85
B) 19.3
C) 3.24
D) 14.9
E) 8.62

Ans:

$$\Delta A = 2\alpha A_0 \Delta T_C\ ;\ \Delta T_C = \frac{5}{9}\Delta T_F = \frac{5}{9}\times 65 = 36.1\ ℃$$

$$\alpha = \frac{\beta}{3} = \frac{2.7\times 10^{-5}}{3} = 9\times 10^{-6}/℃$$
$$\Delta A = 2\alpha A_0 \cdot \Delta T_C = 2\times 9\times 10^{-6}\times 60\times 150\times 36.1 = 5.85\ cm^2$$

Q10.

A 1.0 kg block of ice at -20°C is added to a thermally insulated container containing 0.1 kg cold water at 0°C. Which of the following statement describes the situation of ice-water system after thermal equilibrium is reached in the container.

A) Some of the water freezes and the ice block gets larger.
B) Some of the ice melts and the ice block gets smaller.
C) The water cools down until thermal equilibrium is established.
D) The ice melts until thermal equilibrium is established.
E) none of the given choices.

Ans:

A

Q11.

In a thermodynamic process, the internal energy of a system in a container with adiabatic walls decreased by 800 J. Which statement is correct?

A) The system performed 800 J of work on its surroundings.
B) The system lost 800 J of heat in this process.
C) The system gained 800 J of heat in this process.
D) The surroundings performed 800 J of work on the system.
E) The 800 J of work done by the system was equal to the 800 J of heat gained by the system from its surroundings.

Ans:

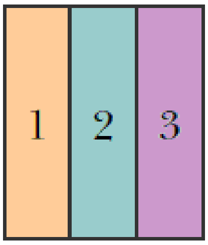
$\Delta E_{int} = Q - W$, *For adiabatic system* $Q = 0$

Then $W = -\Delta E_{int} = -(-800) = +800\text{ J}$

Q12.

Figure 3 shows a composite slab of three different materials 1, 2 and 3 with identical thicknesses, cross sectional area, and with thermal conductivities $k_2 > k_1 > k_3$. The transfer of energy through them is nonzero and steady. Rank the materials according to the temperature difference ΔT across them, **greatest first**.

Figure # 3



A) 3, 1, 2
B) 1, 2, 3
C) 2, 1, 3
D) 3, 2, 1
E) 1, 3, 2

Ans:

$P = \frac{kA\Delta T}{L}$. In steady state across a composite slabs with same A and L

Then $\Delta T \propto \frac{1}{k}$

Then $k_2 > k_1 > k_3 \Rightarrow \Delta T_2 < \Delta T_1 < \Delta T_3$

Q13.

When an amount of heat of 35.1 J was added to a particular ideal gas, the volume of the gas changed from 50.0 cm^3 to 100 cm^3 while the pressure remained at 1.00 atm. If the quantity of gas present was 2.00 $\times 10^{-3}$ mol, find the value of specific heats C_V and C_p(in J/mol.K), respectively.

A) 49.5 and 57.8
B) 57.8 and 49.5
C) 26.1 and 34.4
D) 51.1 and 61.5
E) 29.5 and 37.8

Ans:

$$\Delta Q_P = nC_p\Delta T;\ W_p = P\Delta V = nR\Delta T \ \Rightarrow n\Delta T = \frac{P\Delta V}{R}$$

$$\Delta Q_P = C_p \cdot n\Delta T = C_p \cdot \frac{P\Delta V}{R}$$

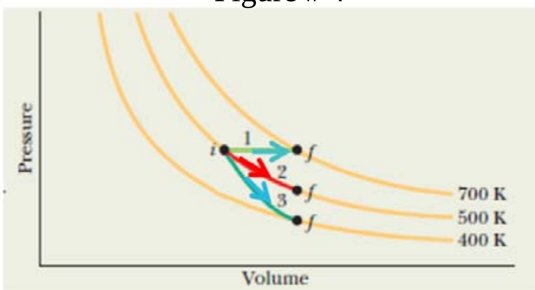
$$C_p = \frac{\Delta Q_P \times R}{P\Delta V} = \frac{35.1 \times 8.31}{1.01 \times 10^5 \times 50 \times 10^{-6}} = 57.76 = 57.8\, J/mol.k$$

$$C_v = C_p - R = 57.8 - 8.31 = 49.5\, J/mol.k$$

Q14.

Rank the three processes 1, 2, and 3 shown in **Figure 4** according to the magnitude of the change in internal energy of an ideal monatomic gas, **greatest first.**

Figure # 4



A) 1, 3, 2
B) 2, 3, 1
C) 1, 2, 3
D) 2, 1, 3
E) 3, 1, 2

Ans:

$$\Delta E_{int} = nC_v\Delta T$$

$$\Delta E_{int} \propto \Delta T\ for\ constant\ n\ and\ C_v$$

$$\Delta T_1 = 700 - 500 = 200\ k$$

$$\Delta T_2 = 500 - 500 = 0$$

$$\Delta T_3 = 400 - 500 = -100\ k$$

Q15.

Two moles of a monatomic ideal gas with an RMS speed of 254 m/s are contained in a tank that has a volume of 0.150 m^3. If the molar mass of the gas is 0.390 kg/mole, what is the pressure of the gas?

A) 1.12×10^5 Pa.
B) 7.17×10^5 Pa.
C) 2.22×10^4 Pa.
D) 3.25×10^6 Pa.
E) 6.87×10^4 Pa.

Ans:

$$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3}{M} \times \frac{PV}{n}} \quad Then\ P = \frac{nMv_{rms}^2}{3V}$$

$$P = \frac{nMv_{rms}^2}{3V} = \frac{2 \times 0.39 \times (254)^2}{3 \times 0.15} = 1.12 \times 10^5 P_a$$

Q16.

Two moles of an ideal gas (γ = 1.40) expand adiabatically from a pressure of 5.00 atm and a volume of 12.0 liters to a final volume of 30.0 liters. What is the final temperature of the gas?

A) 253 K
B) 365 K
C) 199 K
D) 311 K
E) 301 K

Ans:

$$T_f V_f^{\gamma-1} = T_i V_i^{\gamma-1}; \ T_f = T_i \left(\frac{V_i}{V_f}\right)^{\gamma-1}$$

$$but\ T_i = \frac{P_i V_i}{nR} = \frac{5 \times 1.01 \times 10^5 \times 12 \times 10^{-3}}{2 \times 8.31} = 364.4\ K$$

$$T_f = T_i \left(\frac{V_i}{V_f}\right)^{r-1} = 364.4 \times \left(\frac{12}{30}\right)^{0.4} = 252.6\ K$$

Q17.

A 7.00 g ice cube at −10.0°C is placed in a lake whose temperature is 10.0 °C. Calculate the change in entropy of the ice cube as the ice cube comes to thermal equilibrium with the lake. The specific heat of ice is 2220 J/kg.K.

A) +10.2 J /K
B) −15.5 J /K
C) +19.2 J /K
D) +2.12 J /K
E) +7.12 J /K

Ans:

$$\Delta S = m_{ice} \times c_{ice} \times l_n\left(\frac{T_{f-ice}}{T_{i-ice}}\right) + \frac{m_{ice} \times L_f}{T_{fice}} + m_{ice} \times C_{water} \times \left(\frac{T_{f-water}}{T_{i-water}}\right)$$

$$= m_{ice}\left[c_{ice} \times l_n\left(\frac{T_{fice}}{T_{i-ice}}\right) + \frac{L_f}{T_{f-ice}} + C_{water} \times l_n\left(\frac{T_{f-water}}{T_{i-water}}\right)\right]$$

$$= 7 \times 10^{-3}\left[2220 l_n\left(\frac{273}{263}\right) + \frac{333 \times 10^3}{273} + 4190 \times l_n\left(\frac{283}{273}\right)\right] = 10.2\, J/K$$

Q18.

An ideal engine absorbs heat at 527 °C and rejects heat at 127 °C. If the engine delivers 750 Watts of power, how much heat it absorbs in one minute?

A) 90.0 kJ
B) 52.7 kJ
C) 75.0 kJ
D) 37.0 kJ
E) 22.5 kJ

Ans:

$$\varepsilon_C = 1 - \frac{T_L}{T_H} = \frac{W}{Q_H} \Rightarrow Q_H = \frac{W}{\left(1 - \frac{T_L}{T_H}\right)}$$

$$Q_H = \frac{750}{\left(1 - \frac{273+127}{273+527}\right)} = \frac{750}{1 - 0.5} = 1500 \text{ J}$$

$$Q_H\ (in\ 60\ \text{sec}) = 1500 \times 60 = 90000 = 90.0\ kJ$$

Q19.

A Carnot heat pump transfer energy as heat to a house with inside temperature at 21°C when the outdoor temperature is –15°C. For each joule of electric energy required to operate the pump, how much heat energy is transferred to the building?

A) 8.2 J
B) 2.8 J
C) 4.7 J
D) 9.9 J
E) 11 J

Ans:

$$K = \frac{T_H}{T_H - T_L} = \frac{Q_H}{W} \Rightarrow Q_H = W\left(\frac{T_H}{T_H - T_L}\right)$$

$$W = 1\,J$$

$$Then\ Q_H = 1\left(\frac{273 + 21}{21 - (-15)}\right) = 8.2\,J$$

Q20.

Three Carnot engines operate between temperature limits of (a) 400K and 500 K, (b) 500K and 600 K, and (c) 400K and 600 K. Each engine extracts the same amount of energy per cycle from the high-temperature reservoir. Rank the magnitudes of the work done by the engines per cycle, **greatest first**.

A) c, a, b
B) a, b, c
C) b, c, a
D) c, b, a
E) a, c, b

Ans:

$$W = Q_H \cdot \varepsilon_C \Rightarrow W \propto \varepsilon_C\ (for\ constant\ Q_H)$$

$$But\ \varepsilon_C = 1 - \frac{T_L}{T_H};\quad \varepsilon_a = \frac{500 - 400}{500} = 20\,\%;\quad \varepsilon_b = \frac{600 - 500}{600} = 16.7\%$$

$$\varepsilon_c = \frac{600 - 400}{600} = 33.3\,\%$$
