Q1.

A sinusoidal wave is travelling on a string, and is given by:

$$y(x,t) = 0.020 \sin(0.35x - 85t + \pi/2),$$

where x is in meters and t is in seconds. What is the transverse speed of the particle located at x = 0.030 m when t = 0.025 s?

A) 1.5 m/s
B) 1.7 m/s
C) 2.4 m/s
D) 6.6 m/s
E) zero

Ans:

$$|u| = +\omega y_m cos(kx - \omega t + \pi/2)$$

$$= 85 \times 0.02 \times \cos(0.35 \times 0.03 - 85 \times 0.025 + \pi/2) = 1.5\ m/s$$

Q2.

A string, under a tension of 7.2 N and fixed at both ends, oscillates in a third-harmonic standing wave pattern. The displacement of the string is given by:

$$y = (0.10)(\sin \pi x/2)(\cos 15\pi t) \text{ (SI units)},$$

where x is in meters and t is in seconds. The mass of the string is

A) 48 g
B) 33 g
C) 25 g
D) 57 g
E) 38 g

Ans:

$$v = \frac{\omega}{k} \Rightarrow v = \frac{15\pi}{\pi/2} = 30\ m/s$$

$$but\ v = \sqrt{\frac{\tau}{\mu}} \Rightarrow \mu = \frac{\tau}{v^2} = \frac{7.2}{(30)^2} = 8 \times 10^{-3}\ kg/m$$

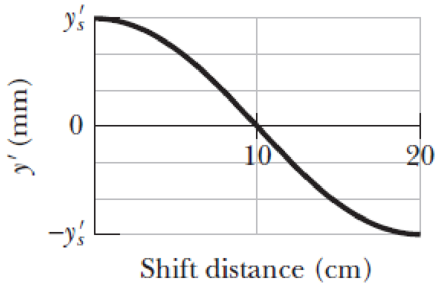
$$L = \frac{3\lambda}{2} = \frac{3}{2} \times \frac{2\pi}{k} = 3 \times \frac{\pi}{\pi/2} = 6\ m$$

$$m = \mu \times L = 8 \times 10^{-3} \times 6 = 48 \times 10^{-3} kg = 48\ g$$

Q3.

Two identical sinusoidal waves, each of frequency 100 Hz, are sent along the same string travelling in the same direction. **FIGURE 1** shows the amplitude of the resultant wave versus the shift distance (how far one wave is shifted from the other). What is the speed of waves on the string?

Figure 1



A) 20 m/s
B) 10 m/s
C) 40 m/s
D) 50 m/s
E) 60 m/s

Ans:

$$From\ graph\ \lambda = 20\ cm = 0.2\ m$$

$$f = 100\ Hz$$

$$v = \lambda f = 0.2 \times 100 = 20\ m/s$$

Q4.

A transverse sinusoidal wave, of wavelength λ, is travelling on a string. For the maximum transverse speed of any particle on the string to be equal to the wave speed, the amplitude of the wave is

A) λ/2π
B) 2λ/π
C) λ
D) 2π/λ
E) π/2λ

Ans:

$$|u_{max}| = \omega y_m = v, \quad v = \frac{\omega}{k} = \frac{\omega}{2\pi/\lambda} = \frac{\omega\lambda}{2\pi}$$

$$v = \omega y_m \Rightarrow \frac{\not{\omega}\lambda}{2\pi} = \not{\omega} y_m \Rightarrow y_m = \frac{\lambda}{2\pi}$$

Q5.

Two speakers (S_1, S_2), emitting sound waves of frequency 340 Hz and separated by a distance of 3.0 m, are driven by the same oscillator, as shown in **FIGURE 2**. A listener starts walking from point A to S_2 along the line that joins A and S_2. How many points of destructive interference will he observe? Speed of sound in air = 340 m/s.

A) 4
B) 1
C) 5
D) 7
E) 2

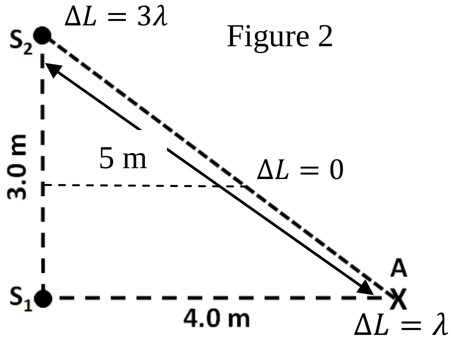


Figure 2

Ans:

$$\lambda = \frac{v}{f} = \frac{340}{340} = 1.0\, m$$

$$At\ A, \Delta L = 5 - 4 = 1.0\, m = \lambda$$

$$At\ S_2\, , \Delta L = 3.0\, m = 3\lambda$$

$$Points\ of\ destructive\ interference\ (between\ \Delta L = \lambda\ and\ 3\lambda) = 4$$

Q6.

A standing wave is set up in a tube that is closed at one end. The standing wave has three nodes and a frequency of oscillation of 250 Hz. What is the length of the tube? Speed of sound in air = 343 m/s.

A) 1.7 m
B) 2.1 m
C) 3.5 m
D) 8.1 m
E) 2.5 m

Ans:

$For\ a\ pipe\ closed\ at\ one\ end\ resonance\ frequency\ f_m$

$$f_m = \frac{mv}{4L}\ (m = 1, 3, 5), f_5 = 250 = \frac{5v}{4L}$$

$$L = \frac{5v}{4f_5} = \frac{5 \times 340}{4 \times 250} = 1.7\, m$$

Q7.

A stationary observer sends a sound wave of frequency 500 Hz toward a car approaching him with a speed of 15.0 m/s. What reflected frequency will be detected by the observer? Speed of sound = 343 m/s.

A) 546 Hz
B) 530 Hz
C) 458 Hz
D) 500 Hz
E) 522 Hz

Ans:

$$f' = f_0\left(\frac{v + v_{car}}{v - v_{car}}\right) = 500 \times \left(\frac{343 + 15}{343 - 15}\right) = 546\ Hz$$

Q8.

A source emits sound waves isotropically. The intensity of sound at a distance of 5.00 m from the source is 1.92×10^{-4} W/m^2. What is the sound level at a distance of 10.0 m from the source?

A) 76.8 dB
B) 79.8 dB
C) 82.8 dB
D) 85.8 dB
E) 88.9 dB

Ans:

$$I = \frac{P}{4\pi R^2} \Rightarrow \frac{I_{10}(R = 10)}{I_5(R = 5)} = \frac{5^2}{10^2}$$

$$\Rightarrow I_{10} = \frac{25}{100} I_5 = 0.25 \times 1.92 \times 10^{-4} = 4.8 \times 10^{-5}\ W/m$$

$$\beta = 10 \log\left(\frac{I_{10}}{I_0}\right) = 10 \log\left(\frac{4.8 \times 10^{-5}}{10^{-12}}\right) = 76.8\ dB$$

Q9.

Which one of the following statements is **WRONG**?

A) Two bodies are in thermal equilibrium with each other if their temperatures are different.
B) If two bodies are in thermal equilibrium, they must have the same temperature.
C) If two bodies are in thermal equilibrium, they do not exchange heat with each other.
D) If two bodies are in thermal contact, they can have initially different temperatures.
E) Two bodies in thermal equilibrium with a third, are in thermal equilibrium with each other.

Ans:

A

Q10.

A cylinder, with a base area of 5.0 cm^2, is initially at 10 ^oC and contains 80 cm^3 of mercury. If the temperature of the cylinder and mercury rises to 90 ^oC, what is the increase in the mercury level? Ignore the expansion of the cylinder. The coefficient of volume expansion of mercury is 1.8×10^{-4} $(^oC)^{-1}$.

A) 0.23 cm
B) 0.75 cm
C) 0.13 cm
D) 0.29 cm
E) 0.54 cm

Ans:

$$\Delta V' = V_0\beta\Delta T = 80 \times 1.8 \times 10^{-4} \times 80 = 1.152\ cm^3$$

$$\Delta h' = \frac{\Delta V'}{A} = \frac{1.152}{5} = 0.23\ cm$$

Q11.

A block of ice, whose mass is 100 g, is initially at – 10.0 °C. It is supplied with 30.0 kJ of heat. What is the final state? The specific heat of ice is 2220 J/kg.K.

A) A mixture of ice and water at 0 °C.
B) Solid ice at a temperature less than 0 °C.
C) Solid ice only at 0 °C.
D) Liquid water only at 0 °C.
E) Water at a temperature higher than 0 °C.

Ans:

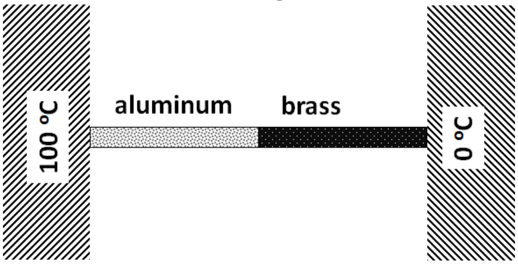
$$m_{ice-melted} = \frac{\Delta Q}{\Delta L_f + L_{ice} \times 10} = \frac{30 \times 1000}{2220 \times 10 + 333{,}000} = 0.0845\ kg = 84.5\ g$$

$$m_{ice-remaining} = m_{ice} - m_{ice-melted} = 100 - 84.5 = 15.5\ g$$

Q12.

An aluminum rod and a brass rod, of the same length and cross sectional area, are welded end-to-end and placed between two reservoirs, as shown in **FIGURE 3**. In steady state, what is the temperature at the junction between the two rods?
[Thermal conductivity: k_{aluminum} = 235 W/m.K, k_{brass} = 109 W/m.K]

Figure 3



A) 68.3 °C
B) 31.7 °C
C) 50.0 °C
D) 46.4 °C
E) 54.7 °C

Ans:

m steady state

$$\frac{k_{Al} \times A(100 - T_j)}{L} = \frac{k_{Brass} \times A(T_j - 0)}{L}$$

$$\Rightarrow T_j(k_{Al} + k_{Brass}) = k_{Al} \times 100$$

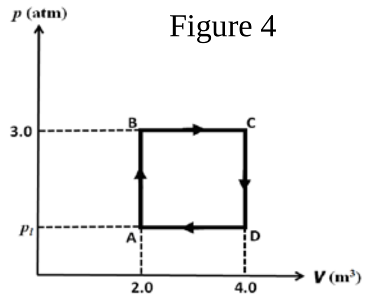
$$T_j = \frac{k_{Al} \times 100}{(k_{Al} + k_{Brass})} = \frac{235 \times 10}{235 + 109} = 68.3°C$$

Q13.

An ideal monatomic gas is carried around the cycle ABCDA shown in **FIGURE 4**. The net work done in the cycle is 4.0×10^5 J. Find the heat added to the gas in process AB.

A) 6.0×10^5 J
B) 4.0×10^5 J
C) 5.0×10^5 J
D) 2.0×10^5 J
E) 3.0×10^5 J

Figure 4



Ans:

$$W = R_f V_f - R_i V_i = nR\Delta T = 4.0 \times 10^5 \, J$$

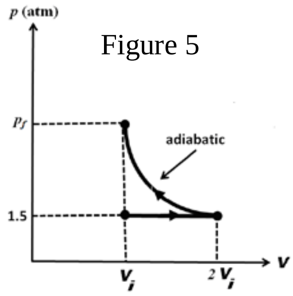
$$\Delta Q_{AB} = nc_v\Delta T = n \times \frac{3}{2} R \times \Delta T = \frac{3}{2} \times nR\Delta T == \frac{3}{\not{2}} \times \not{4}^{2} \times 10^5 = 6 \times 10^5 \, J$$

Q14.

An ideal monatomic gas, initially at pressure p_i = 1.5 atm, is allowed to expand at constant pressure until its volume is doubled, as shown in **FIGURE 5**. The gas is then compressed adiabatically until it reaches its initial volume. What is the final pressure of the gas?

A) 4.8 atm
B) 6.0 atm
C) 2.2 atm
D) 3.0 atm
E) 5.4 atm

Figure 5



Ans:

$$P_f = P_i \left(\frac{V_i}{V_f}\right)^{\gamma} = 1.5 \times \left(\frac{2}{1}\right)^{5/3} = 4.8 \, atm$$

Q15.

A 3.0-L cylinder contains a diatomic ideal gas at a pressure of 2.0 atm. What is the internal energy of the gas?

A) 1.5 kJ
B) 0.91 kJ
C) 6.0 kJ
D) 3.1 kJ
E) 2.7 kJ

Ans:

$$E_{int} = nC_vT = \frac{5}{2}(nRT) = \frac{5}{2} pV$$

$$E_{int} = \frac{5}{2} \times P \times V = \frac{5}{2} \times 2 \times 1.01 \times 10^5 \times 3 \times 10^{-3} = 1515 \, J = 1.5kJ$$

Q16.

A quantity of an ideal monatomic gas expands to twice its initial volume. The process may be free expansion, isobaric, or isothermal. Rank these processes in order of the work done by the gas, largest first.

A) isobaric, isothermal, free expansion
B) isobaric, free expansion, isothermal
C) isothermal, free expansion, isobaric
D) isothermal, isobaric, free expansion
E) free expansion, isothermal, isobaric

Ans:

$$W_{free-expansion} = 0$$

$$W_{isobaric} = P\Delta V = nR\Delta T$$

$$W_{isothermal} = nRTln\left(\frac{v_f}{v_i}\right) = nRTln\left(\frac{2}{1}\right) = 0.693\, nRT$$

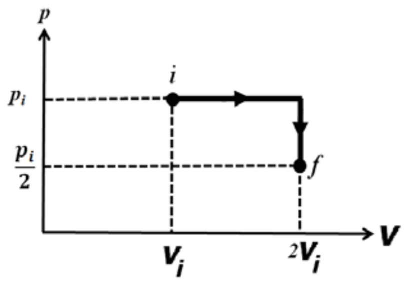
$$W_{isobaric} > W_{isothermal} > W_{free-expansion}$$

Q17.

Two moles of an ideal gas undergoes the expansion shown in **FIGURE 6**. What is the change in the entropy of the gas as it expands from state ***i*** to state ***f*** ?

A) +11.5 J/K
B) +46.1 J/K
C) –46.1 J/K
D) –11.5 J/K
E) +69.1 J/K

Figure 6



Ans:

$$\Delta S = nRl_n\left(\frac{V_f}{V_i}\right) + nC_v l_n\left(\frac{T_f}{T_i}\right)$$

$$\frac{T_f}{T_i} = \frac{P_f V_f}{P_i V_i}$$

$$\Delta S = nR\left[ln\left(\frac{v_f}{v_i}\right) + \frac{3}{2}ln\left(\frac{P_f V_f}{P_i V_i}\right)\right]$$

$$= 2 \times 8.314\left[ln(2) + \frac{3}{2}ln(1)\right] = 11.5\, J/K$$

Q18.

A Carnot heat engine operates between reservoirs at temperatures of 800 K and 300 K, and does 860 J of work every cycle. The change in the entropy of the hot reservoir per cycle is

A) – 1.72 J/K
B) + 1.72 J/K
C) – 4.58 J/K
D) + 4.58 J/K
E) Zero

Ans:

$$\Delta S = -\frac{Q_H}{T_H} \; but \; Q_H = \frac{W}{\varepsilon} \; and \; \varepsilon = \frac{T_H - T_C}{T_H} = \frac{800 - 300}{800} \Rightarrow \varepsilon = 0.625$$

$$Then \; \Delta S = -\frac{Q_H}{T_H} = -\frac{W}{T_H \times \varepsilon} = -\frac{860}{800 \times 0.625} = -1.72 \, J/K$$

Q19.

A refrigerator has a coefficient of performance of 2.50 and a power of 500 W. Liquid water (0.500 kg at 0 ^{o}C) is placed in the cold chamber of the refrigerator. How long does it take to freeze all the water to ice at 0 ^{o}C?

A) 133 s
B) 832 s
C) 33.3 s
D) 251 s
E) 74.6 s

Ans:

$$Heat \; removed \; per \; second = Q_L = W \times K = 500 \times 2.5 = 1250 \, J$$

$$Total \; heat \; to \; be \; removed \; Q_{total} = 0.5 \times 333{,}000 = 166{,}500 \, J$$

$$Time \; required \; to \; remove \; Q_{total} = \frac{Q_{total}}{Q_L} = \frac{166{,}500}{1250} = 133.2 \, sec$$

Q20.

A lake is at room temperature. An ice cube, with an initial temperature of – 10 °C, is dropped into the lake. When thermal equilibrium is reached, let ΔS_1 be the change in the entropy of ice, and ΔS_2 be the change in the entropy of the lake. Which of the following statements is **CORRECT**?

A) $\Delta S_1 > 0$ and $\Delta S_2 < 0$
B) $\Delta S_1 > 0$ and $\Delta S_2 > 0$
C) $\Delta S_1 < 0$ and $\Delta S_2 < 0$
D) $\Delta S_1 < 0$ and $\Delta S_2 > 0$
E) The total entropy change is zero.

Ans:

A