Q1.

A sinusoidal wave with an amplitude of 1.00 m and a frequency of 100 Hz travels at 200 m/s in the positive *x*-direction. At *t* = 0 s, the point at *x* = 1.00 m has positive maximum displacement. Which of the following equations represent the wave displacement as it travels.

A) y(*x*, *t*) = (1.00 m) sin [π *x* - (200π)*t* - π/2]
B) y(*x*, *t*) = (1.00 m) sin [π *x* + (200π))*t*]
C) y(*x*, *t*) = (1.00 m) sin [π *x* - (100π)*t* - π/2]
D) y(*x*, *t*) = (1.00 m) sin [π *x* - (100π)*t*]
E) y(*x*, *t*) = (1.00 m) sin [π *x* + (300π)*t* + π/2]

Ans:

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

$$\omega = 2\pi f = 2\pi \times 100 = 200\,\pi$$

$$k = \frac{\omega}{v} = \frac{200\,\pi}{200} = \pi$$

$$at\ t = 0, x = 1.0\,m, y\,(1,0) = 1.0\,m$$

$$y\,(1,0) = y_m \sin(kx + \phi) \Rightarrow 1 = 1\sin(\pi + \phi)$$

$$\phi = sin^{-1}\left(\frac{y(1,0)}{y_m}\right) - \pi = \frac{\pi}{2} - \pi = -\frac{\pi}{2}$$

$$y(x,t) = y_m sin\left(kx - \omega t - \frac{\pi}{2}\right)$$

Q2.

A string with linear mass density 2.00 g/m is stretched along the *x*-axis with a tension of 5.00 N. The string is tied at one end to a 100 Hz simple harmonic oscillator that vibrates perpendicular to the string with an amplitude of 2.00 mm. The average power transported by the wave is:

A) 0.079 W
B) 1.34 W
C) 0.834 W
D) 1.78 W
E) 2.45 W

Ans:

$$P_{avg} = \frac{1}{2}\mu v \omega^2 y_m^2 \Longrightarrow v = \sqrt{\frac{\tau}{\mu}} = \sqrt{\frac{5}{2\times 10^{-3}}} = 50\,m/s$$

$$P_{avg} = \frac{1}{2} \times 2 \times 10^{-3} \times 50 \times (200\pi)^2 \times (2\times 10^{-3})^2 = 0.07887\ \text{W}$$

Q3.

If the frequency of the second-longest wavelength for standing waves on a 240-cm-long string that is fixed at both ends is 50 Hz, what is the frequency of the third-longest wavelength?

A) 75 Hz
B) 50 Hz
C) 85 Hz
D) 40 Hz
E) 35 Hz

Ans:

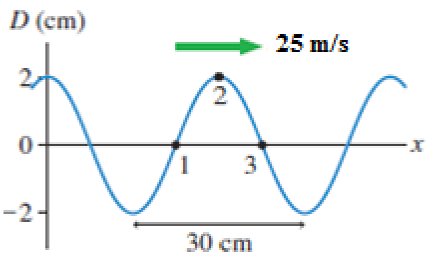
$$f_2 = \frac{2v}{2L};\ f_3 = \frac{3v}{2L};\ \frac{f_3}{f_2} = \frac{3}{2}$$

$$f_3 = \frac{3}{2} \times f_2 = \frac{3}{2} \times 50 = 75\ \text{Hz}$$

Q4.

FIGURE 1 shows a snapshot graph of a wave traveling to the right along a string at 25 m/s. At this instant, what are the velocities of points 1, 2, and 3 on the string, respectively?

Figure 1



A) –11 m/s, 0, +11 m/s
B) –11 m/s, 0, –11 m/s
C) 0, –11 m/s, 0
D) 0, +11 m/s, –11 m/s
E) –19 m/s, 0, +19 m/s

Ans:

$$|u_{max}| = \omega y_m = 2\pi f y_m$$

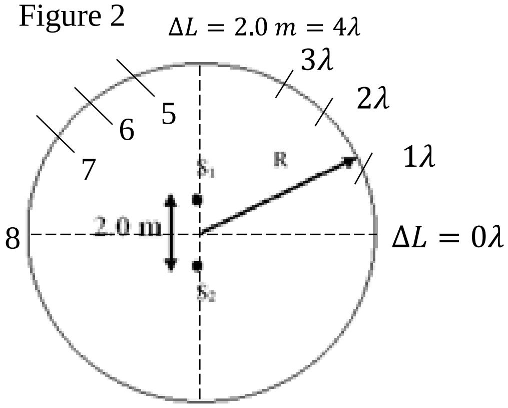
$$f = \frac{v}{\lambda} = \frac{25}{0.3} = 83.33\ m/s$$

$$|u_{max}| = 2\pi \times 83.33 \times 2 \times 10^{-2} = 10.47\ m/s = 11\ m/s$$

Q5.

Two transmitters, S_1 and S_2, shown in the **FIGURE 2**, emit identical sound waves at a frequency of 686 Hz. The transmitters are separated by a distance of 2.0 m. Consider a big circle of radius R with its center halfway between these transmitters. How many interference maxima are there on this big circle?

Figure 2



A) 16
B) 12
C) 14
D) 18
E) 10

Ans:

$$\lambda = \frac{v}{f} = \frac{343}{686} = 0.5\ m$$

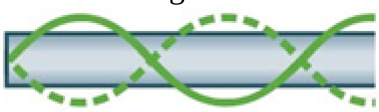
Number of Maxima =16

Q6.

A tube closed at one end resonates in the standing wave pattern shown in the **FIGURE 3**. If the frequency of the emitted sound is 858 Hz, what is the length of the tube?

A) 0.500 m
B) 0.300 m
C) 1.50 m
D) 1.00 m
E) 2.00 m

Figure 3



Ans:

$$f_5 = \frac{5v}{4L}$$

$$L = \frac{5v}{4f_5} = \frac{5 \times 343}{4 \times 858} = 0.5\ \text{m}$$

Q7.

Two cars are approaching each other at the same speed when one of the drivers sounds the horn of his car, which has a frequency of 500 Hz. The other driver hears the frequency as 520 Hz. What is the speed of the cars?

A) 6.73 m/s
B) 13.1 m/s
C) 2.54 m/s
D) 1.55 m/s
E) 5.45 m/s

Ans:

$$f' = f_0\left(\frac{v+v_D}{v-v_s}\right) = f_0\left(\frac{v+v_c}{v-v_c}\right) = 500\left(\frac{343+v_c}{343-v_c}\right) = 520$$

$$\frac{520}{500} = \frac{343+v_c}{343-v_c}$$

$$1.04(343-v_c) = 343+v_c$$

$$v_c = \frac{13.72}{2.04} = 6.73\ m/s$$

Q8.

A source emits sound with equal intensity in all directions. If the displacement amplitude is tripled, the sound level increases by:

A) 9.54 dB
B) 8.45 dB
C) 10.5 dB
D) 7.50 dB
E) 6.00 dB

Ans:

$$I \propto\ s_m^2 \Longrightarrow \frac{I_2}{I_1} = \frac{s_{m1}^2}{s_{m2}^2} = 9$$

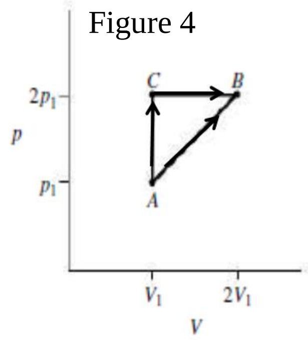
$$\Delta\beta\ = 10\left[log\left[\frac{I_2}{I_0}\right] - log\left[\frac{I_1}{I_0}\right]\right] = 10\left[log9 + log\left[\frac{I_1}{I_0}\right] - log\left[\frac{I_2}{I_0}\right]\right]$$

$$\Delta\beta\ = 10 \times log_{10}(9) = 9.54\ \text{ dB}$$

Q9.

An ideal gas expands from the state $A(p_1, V_1)$ to the state $B(p_2, V_2)$, where $p_2 = 2p_1$ and $V_2 = 2V_1$ via paths *AB and ACB*, as shown in **FIGURE 4**. Find the path which requires more heat and the heat difference between the two paths, respectively?

Figure 4



A) Path *ACB*, $+p_1V_1/2$
B) Path *ACB*, $-p_1V_1/2$
C) Path *AB*, $+3p_1V_1/2$
D) Path *AB*, $-3p_1V_1/2$
E) Path *ACB*, $+2\,p_1V_1$

Ans:

$$\Delta E_{AB} = Q_{ACB} - W_{ACB} = Q_{AB} - W_{AB}$$

$$Q_{ACB} - Q_{AB} = W_{ACB} - W_{AB}$$

$$W_{ACB} = 2P_1(2V_1 - V_1) = 2P_1V_1$$

$$W_{AB} = P_1(2V_1 - V_1) + \frac{P_1}{2}(2V_1 - V_1)$$

$$W_{AB} = P_1V_1 + \frac{P_1V_1}{2} = \frac{3}{2}P_1V_1$$

$$Q_{ACB} - Q_{AB} = W_{ACB} - W_{AB}$$

$$= 2P_1V_1 - \frac{3}{2}P_1V_1 = \frac{+P_1V_1}{2}$$

Q10.

A glass container whose volume is 1.00 L at 0.00 °C is completely filled with a liquid at this temperature. When the filled container is warmed to 55.0 °C, a volume of 8.95 cm^3 of the liquid overflow. If the coefficient of linear expansion of glass is 5.67×10^{-6} /C°, then find the coefficient of volume expansion of the liquid.

A) 18.0×10^{-5} /C°
B) 2.20×10^{-5} /C°
C) 7.65×10^{-5} /C°
D) 11.5×10^{-5} /C°
E) 14.1×10^{-5} /C°

Ans:

$$\Delta V_{overflow} = \Delta V_{liquid} - \Delta V_{glass} = V_0 \Delta T(\beta_{liquid} - \beta_{glass})$$

$$\beta_{liquid} = \frac{\Delta V_{overflow}}{V_0 \times \Delta T} + \beta_{glass} = \frac{8.95}{10^3 \times 55} + 3 \times 5.67 \times 10^{-6}$$

$$\beta_{liquid} = 17.97 \times 10^{-5} = 18.0 \times 10^{-5}/C°$$

Q11.

A block of mass 125 g at a temperature of 90.0 °C is placed in a cup containing 0.326 kg of water at 20.0 °C. The block and the water reach an equilibrium temperature of 22.4 °C. Neglecting the heat capacity of the cup, find the specific heat of the block.

A) 388 J/kg.C°
B) 431 J/kg.C°
C) 453 J/kg.C°
D) 712 J/kg.C°
E) 600 J/kg.C°

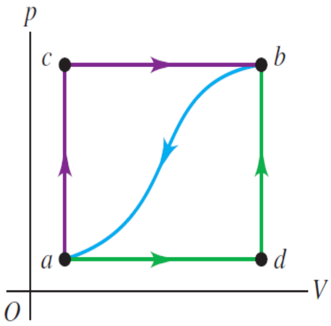
Ans:

$$C_b = \frac{m_w \times c_w \times (22.4 - 20)}{m_b \times (90 - 22.4)} = \frac{0.326 \times 4187 \times (2.4)}{0.125 \times 67.6} = 387.7 \text{J/kg} \cdot \text{C}°$$

Q12.

As shown in **FIGURE 5**, when a system is taken from state *a* to state *b* along the path *acb*, 90 J of heat flows into the system and 60 J of work is done by the system. How much heat flows into the system along path *adb* if the work done by the system is 15 J?

Figure 5



A) + 45 J
B) + 60 J
C) + 30 J
D) – 30 J
E) – 45 J

Ans:

$$\Delta E_{ab} = Q_{acb} - W_{acb} = Q_{adb} - W_{adb}$$

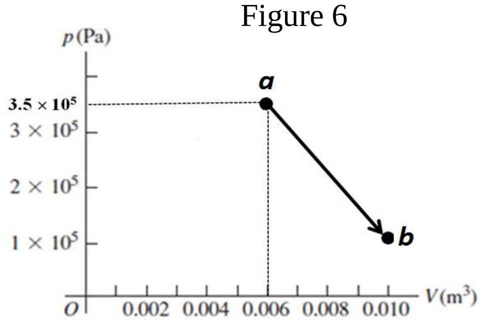
$$\Delta E_{ab} = Q_{acb} - W_{acb} = 90 - 60 = 30\ J$$

$$Q_{adb} = \Delta E_{ab} + W_{adb} = 30 + 15 = 45\ J$$

Q13.

One mole of an ideal monatomic gas is taken along the path *ab* shown as the solid line in **FIGURE 6**. Find the amount of heat that is transferred into or out of the gas along the path *ab*.

Figure 6



A) -7.49×10^2 J
B) $+3.00 \times 10^2$ J
C) -2.22×10^2 J
D) $+5.01 \times 10^2$ J
E) -6.22×10^2 J

Ans:

$$\Delta E_{ab} = Q_{ab} - W_{ab}$$

$$Q_{ab} = \Delta E_{int-ab} + W_{ab}$$

$$\Delta E_{int-ab} = nC_v(T_b - T_a) = n \cdot \frac{3}{2} R \left(\frac{P_b V_b}{nR} - \frac{P_a V_a}{nR}\right)$$

$$= \frac{3}{2}(P_b V_b - P_a V_a) = \frac{3}{2}(10^5 \times 0.01 - 3.5 \times 10^5 \times 0.006)$$

$$\Delta E_{int-ab} = -1650 \text{ J}$$

$$W_{ab} = 10^5 \times (0.01 - 0.006) + \frac{(0.01 - 0.006) \times 2.5 \times 10^5}{2} = 400 + 500 = 900 \text{ J}$$

$$Q_{ab} = -1650 + 900 = -750 \text{ J}$$

Q14.

A sample of argon gas (molar mass 40 g) is at four times the absolute temperature of a sample of hydrogen gas (molar mass 2 g). The ratio of the rms speed of the hydrogen molecules to that of the argon is:

A) $\sqrt{5}$
B) 1
C) 1/5
D) 5
E) $1/\sqrt{5}$

Ans:

$$\frac{v_{rms-H}}{v_{rms-A}} = \sqrt{\frac{T_H}{T_A} \times \frac{M_A}{M_H}} = \sqrt{\frac{1}{4} \times 20} = \sqrt{5}$$

Q15.

Two moles of an ideal monatomic gas go through the cycle *abca*. For the complete cycle, 800 J of heat flows out of the gas. Process *ab* is at constant pressure, and process *bc* is at constant volume. States *a* and *b* have temperatures T_a = 200 K and T_b = 300 K, respectively. Find the work *W* for the process *ca*.

A) – 2463 J
B) + 1985 J
C) + 1677 J
D) – 2233 J
E) – 800.0 J

Ans:

For complete cycle abca $W_{abca} = -Q_{abca} = -800$ J

$$W_{abca} = W_{ab} + W_{bc} + W_{ca} = nR(T_b - T_a) + 0 + W_{ca}$$

$$W_{ca} = W_{abca} - nR(300 - 200) = -800 - 2 \times 8.314 \times 100$$

$$W_{ca} = -2462.8 \text{ J}$$

Q16.

The volume of an ideal gas is halved during an adiabatic compression that increases the pressure by a factor of 2.5. By what factor does the temperature increase?

A) 1.3
B) 1.9
C) 2.5
D) 1.7
E) 2.2

Ans:

$$P_i V_i^{\gamma} = P_f V_f^{\gamma} \Rightarrow \frac{P_i}{P_f} = \left(\frac{V_f}{V_i}\right)^{\gamma} \Longrightarrow \gamma = \frac{l_n\left(\frac{P_i}{P_f}\right)}{l_n\left(\frac{V_f}{V_i}\right)} = \frac{l_n\left(\frac{1}{2.5}\right)}{l_n\left(\frac{1}{2}\right)}$$

$$\gamma = \frac{-0.916}{-0.693} = 1.32$$

$$\frac{T_f}{T_i} = \left(\frac{V_i}{V_f}\right)^{\gamma-1} = (2)^{0.32} = 1.248 = 1.3$$

Q17.

Three Carnot engines operate between the two temperature limits of (a) 400 and 500 K, (b) 500 and 600 K, and (c) 400 and 600 K, respectively. 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:

$$W = Q_H \varepsilon_c = \frac{T_H - T_L}{T_H} \cdot Q_H$$

$$\varepsilon_{c-a} = \frac{500 - 400}{500} = 0.2$$

$$\varepsilon_{c-b} = \frac{600 - 500}{600} = 0.167$$

$$\varepsilon_{c-c} = \frac{600 - 400}{600} = 0.33$$

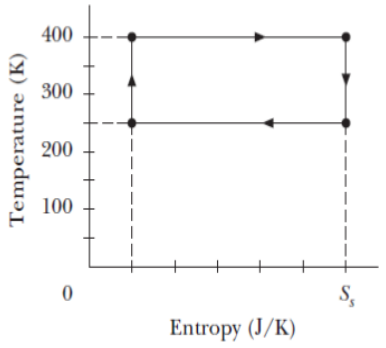
c,a,b

Q18.

FIGURE 7 shows a Carnot cycle on a *T*-*S* diagram, with a scale set by $S_s = 0.60$ J/K. For a full cycle, find the net work done by the system.

A) 75 J
B) 22 J
C) 99 J
D) 31 J
E) 55 J

Figure 7



Ans:

$$For\ complete\ cycle\ Q_{net} - W_{net} = \Delta S = 0$$

$$W_{net} = Q_{net} = \int T ds = Area$$

$$= 150 \times 0.5 = 75 \text{ J}$$

Q19.

5.0 mol of an ideal monatomic gas undergoes a constant pressure process at a pressure of 2.0 atm from an initial volume of 0.5 m^3 to a final volume of 0.3 m^3. What is the change in entropy of the gas during this process?

A) –53 J/K
B) +53 J/K
C) –11 J/K
D) +11 J/K
E) –35 J/K

Ans:

$$\Delta S = nC_p ln\left(\frac{T_f}{T_i}\right) = nc_p ln\left(\frac{V_f}{V_i}\right)$$

$$= 5 \times \frac{5}{2} \times 8.314 \times ln\left(\frac{0.3}{0.5}\right) = -53.09 \text{ J/K}$$

Q20.

A Carnot refrigerator operates on 800 W of power. If the freezing compartment of the refrigerator is at –15.0° C and the outside air is at 35.0° C, calculate the rate at which heat is discharged to the outside air.

A) 4.93×10^3 J/s
B) 1.29×10^3 J/s
C) 7.55×10^3 J/s
D) 8.80×10^3 J/s
E) 9.34×10^3 J/s

Ans:

$$Q_H = Q_L + W$$

$$Q_L = KW = \frac{T_L}{T_H - T_L} \times W = \frac{258}{308 - 258} \times 800$$

$$Q_L = 5.16 \times 800 = 4128 \text{ J/s}$$

$$Q_H = Q_L + W = 4128 + 800 = 4928 \text{ J}$$
