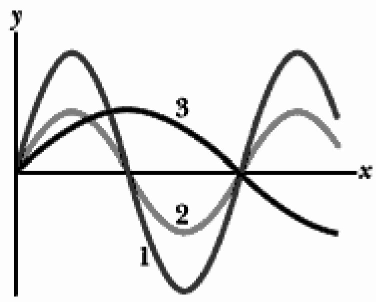
Q1.

FIGURE 1 shows three waves that are separately sent along the same unstretchable string that is kept under constant tension along an x-axis. Rank the waves according to their angular frequency, smallest first.

A) 3, then 1 and 2 tie
B) 1 and 2 tie, then 3
C) 2, then 1 and 3 tie
D) 2 and 3 tie, then 1
E) 1 and 3 tie, then 2



Ans:

$$\omega = kv = \frac{2\pi}{\lambda}\sqrt{\frac{\tau}{\mu}} \Rightarrow \omega \propto \frac{1}{\lambda}$$

$$\lambda_3 > \lambda_1 = \lambda_2$$

$$\omega_3 < \omega_1 = \omega_2$$

Q2.

A sinusoidal wave of frequency 500 Hz has a speed of 350 m/s. How far apart are two points that differ in phase by π/3?

A) 117 mm
B) 701 mm
C) 60.0 mm
D) 233 mm
E) 181 mm

Ans:

$$\Delta\Phi(\lambda) = \frac{\Delta\Phi(\text{rad})}{2\pi} \times \lambda;\ \lambda = \frac{v}{f} = \frac{350}{500} = 0.7\ \text{m}$$

$$\Delta\Phi(\lambda) = \frac{\not\pi}{3} \times \frac{1}{2\not\pi} \times 0.7 = \frac{0.7}{6}\ \text{m} = 117\ \text{mm}$$

Q3.

What phase difference between two identical sinusoidal traveling waves, moving in the same direction along a stretched string, results in the combined wave having an amplitude 1.50 times that of the common amplitude of the two combining waves?

A) 1.45 rad
B) 0
C) 2.57 rad
D) 2.07 rad
E) 1.05 rad

Ans:

$$1.5y_m = 2y_m \cos\left(\frac{\Phi}{2}\right)$$

$$\Phi = 2\cos^{-1}\left(\frac{1.5}{2.0}\right) = 2 \times 41.41 = 82.8° = 1.45 \text{ rad}$$

Q4.

A standing wave on a string results from the sum of two transverse traveling waves given by $y_1 = 0.050 \sin(\pi x - 4\pi t)$ and $y_2 = 0.050 \sin(\pi x + 4\pi t)$, where x, y_1, and y_2 are in meters and t is in seconds. What is the maximum transverse speed of a particle on the string located at
$x = 10$ cm?

A) 0.39 m/s
B) 0.79 m/s
C) 0.11 m/s
D) 2.6 m/s
E) 6.1 m/s

Ans:

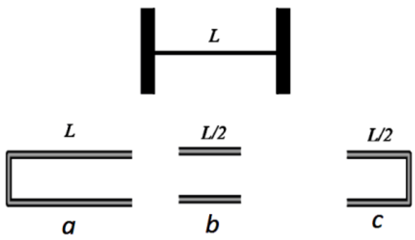
$$|u(\mathrm{x,t})|_{max} = 2y_m\omega \sin(\mathrm{kx})$$

$$= 2 \times 0.050 \times 4\pi \times \sin(\pi \times 0.1) = 1.26 \times \sin(18°) = 0.389 \text{ m/s}$$

Q5.

FIGURE 2 shows a stretched string of length *L* and pipes *a*, *b*, and *c* of different lengths varying from L/2 to L. The string's tension is adjusted until the speed of waves on the string equals the speed of sound waves in the air. The fundamental mode of oscillation is then set up on the string. In which pipe will the sound produced by the string cause resonance and set up the fundamental mode of oscillation?

Figure 2



A) Pipe *c*
B) Pipe *a*
C) Pipe *b*
D) None of them
E) All of them

Ans:

$$v_{string} = v_{sound} = v$$

$$\text{For string } f_{1-string} = \frac{v}{2L}$$

$$\text{For pipe a } f_{1a} = \frac{v}{4L}$$

$$\text{For pipe b } f_{1b} = \frac{v}{2 \times \frac{L}{2}} = \frac{v}{L}$$

$$\text{For pipe c } f_{1c} = \frac{v}{4 \times 2L} = \frac{v}{8L}$$

$$\text{For pipe d } f_{1d} = \frac{v}{4 \times \frac{L}{2}} = \frac{v}{2L} \text{ and } f_{1d} = f_{1-string}$$

Q6.

A sound wave of the form $s = s_m \cos(kx - \omega t + \phi)$ travels at 343 m/s through air in a long horizontal tube. At one instant, air molecule *A* at *x* = 2.00 m is at its maximum positive displacement s_m= 6.00 nm and air molecule *B* at *x* = 2.07 m is at a positive displacement of 2.00 nm. All the molecules between *A* and *B* are at intermediate displacements. What is the angular frequency of the wave?

A) 6.03×10^3 rad/s
B) 1.06×10^3 rad/s
C) 4.32×10^3 rad/s
D) 7.22×10^3 rad/s
E) 12.0×10^3 rad/s

Ans:

$$S_A = S_m \cos(kx_A - \omega t + \Phi);\ S_B = S_m(kx_B - \omega t + \Phi)$$

$$\cos^{-1}\left(\frac{S_A}{S_m}\right) = kx_A - \omega t + \Phi; \cos^{-1}\left(\frac{S_B}{S_m}\right) = kx_B - \omega t + \Phi$$

Subtracting from each other $kx_B - \omega t + \Phi - kx_A + \omega t - \Phi$

$$k(x_B - x_A) = \cos^{-1}\left(\frac{S_B}{S_m}\right) - \cos^{-1}\left(\frac{S_A}{S_m}\right)$$

$$k(2.07 - 2.00) = \cos^{-1}\left(\frac{2}{6}\right) - \cos^{-1}\left(\frac{6}{6}\right)$$

$$k(0.07) = \cos^{-1}\left(\frac{1}{3}\right) - 0 = 70.5° = 1.23 \text{ rad}$$

$$k = \frac{1.23}{0.07} = 17.59$$

$$\omega = k \times v = 17.59 \times 343 = 6032 \text{ rad/s} = 6.03 \times 10^3 \text{ rad/s}$$

Q7.

Two loud speakers are located 3.35 m apart on an outdoor stage. A listener is 18.3 m from one speaker and 19.5 m from the other speaker. During the sound check, a signal generator drives the two speakers in phase with the same amplitude and frequency. The transmitted frequency is swept through the audible range (20.0 Hz to 20.0 kHz). What is the lowest frequency that gives minimum signal (destructive interference) at the listener's location? (v_{sound} = 343 m/s)

A) 143 Hz
B) 286 Hz
C) 215 Hz
D) 429 Hz
E) 108 Hz

Ans:

$$\Delta L = L_2 - L_1 = 19.5 - 18.3 = 1.2 \text{ m}$$

For minima, lowest frequency means largest wavelength

$$\Delta L = \frac{\lambda}{2} \Rightarrow \lambda = 2\Delta L = 2 \times 1.2 = 2.4 \text{ m}$$

$$f = \frac{v}{\lambda} = \frac{343}{2.4} = 142.9 \text{ Hz}$$

Q8.

A train is moving parallel to a highway with a constant speed of 20.0 m/s. A car is traveling in the same direction in front of the train with a speed of 40.0 m/s. The car horn sounds at a frequency of 510 Hz. What frequency does a train passenger observe for the car horn? (v_{sound} = 343 m/s)

A) 483 Hz
B) 338 Hz
C) 544 Hz
D) 111 Hz
E) 611 Hz

Ans:

$$f' = f_0 \left(\frac{v + v_d}{v + v_s}\right) = 510 \times \left(\frac{343 + 20}{343 + 40}\right) = 510 \times 0.9478 = 483.4 \text{ Hz}$$

Q9.

If a gas undergoes an isobaric expansion, which one of the following statements is true?

A) Work is done by the gas.
B) The change in the internal energy is zero.
C) Entropy remains constant.
D) The volume of the gas remains the same.
E) The pressure of the gas decreases uniformly.

Ans:

A

Q10.

At 20.0 ^{0}C, an aluminum ring has an inner diameter of 5.00 cm. To what temperature should the ring be heated to have an inner diameter of 5.05 cm? (α_{Al} =24.0 ×10 $^{-6}$/K)

A) 437 ^{0}C
B) 577 ^{0}C
C) 365 ^{0}C
D) 115 ^{0}C
E) 945 ^{0}C

Ans:

$$\Delta L = L_f - L_0 = L_0 \alpha \Delta T \Rightarrow 5.05 - 5.00 = 5.00 \times 24 \times 10^{-6} \times \Delta T$$

$$\Delta T = \frac{0.05}{5 \times 24 \times 10^{-6}} = 416.7\ ℃$$

$$T_f = T_i + \Delta T = 20 + 416.7 = 436.7 ℃$$

Q11.

How much water remains unfrozen after 50.2 kJ is transferred as heat from 260 g of water initially at 15.0 ^{0}C.

A) 158 g
B) 42.0 g
C) 82.0 g
D) 101 g
E) 251 g

Ans:

$$\text{Heat } Q_{lost} \text{ in cooling} = mc\Delta T$$

$$\text{Heat available } Q_0 = 50.2\ kJ$$

$$Q_{remain} = Q_0 - Q_{lost} = 50200 - 0.26 \times 4190 \times 15 = 33859\ J$$

$$\text{Water Frozen } m_f = \frac{Q_{remain}}{L_f} = \frac{33859}{333 \times 1000} = 0.1017\ kg = 101.7\ g$$

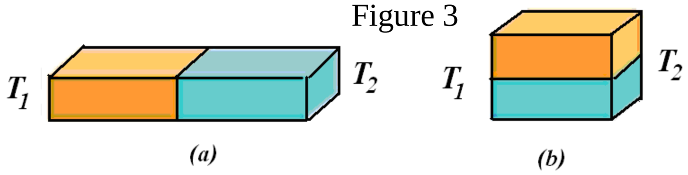
$$\text{Unfrozen Water} = 260 - 101.7 = 158.3\ g$$

Q12.

Two identical rectangular rods of the same metal are welded end to end. The left end of the welded rod is kept at a temperature of T_1 = 0 °C while the right end of the welded rod is kept at a temperature of T_2 =100 °C, as shown in **FIGURE 3a**. In steady state 10 J of heat is conducted through the welded rod in 2.0 min. How much time would be required to conduct 10 J of heat through one rod as shown in **FIGURE 3b**?

A) 1.0 min
B) 0.50 min
C) 2.0 min
D) 1.5 min
E) 2.5 min

Figure 3



Ans:

$$\text{Amount of heat conducted Q} = 10\text{ J} = P_a \times t_a = P_b \times t_b \Rightarrow t_b = t_a \cdot \frac{P_a}{P_b}$$

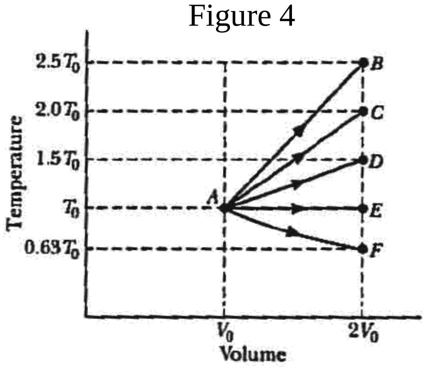
$$P_a = \frac{A \times \Delta T}{\frac{L}{k} + \frac{L}{k}} = \frac{kA\Delta T}{2L};\ P_b = \frac{kA\Delta T}{L}$$

$$t_b = t_a \cdot \frac{P_a}{P_b} = \frac{2 \times \frac{kA\Delta T}{2L}}{\frac{kA\Delta T}{L}} = 1.0\text{ min}$$

Q13.

An ideal monatomic gas at initial temperature T_o (in kelvins) expands from initial volume V_o to final volume $2V_o$ by any of the five processes AB, AC, AD, AE and AF indicated in the *T-V* diagram of **FIGURE 4**. Which of the processes is an isobaric (constant pressure) process?

Figure 4



A) AC
B) AE
C) AF
D) AD
E) AB

Ans:

$$\text{For isobaric Process; P} = \frac{T_i}{V_i} = \frac{T_f}{V_f}$$

$$T_f = T_i \cdot \left(\frac{V_f}{V_i}\right) = 2T_i = 2T_o$$

Process A → C

Q14.

An ideal gas is initially at a pressure of 1.40 atm and has a volume of 3.50 L. It expands isothermally to a final pressure of 0.600 atm. How much heat is transferred during the process?

A) 419 J
B) 124 J
C) 111 J
D) 539 J
E) 271 J

Ans:

$$Q_T = W_T = nRT\,ln\left(\frac{V_f}{V_i}\right);\, nRT = P_iV_i$$

For isothemal process nRT is constant; $P_iV_i = P_fV_f \Rightarrow \frac{V_f}{V_i} = \frac{P_i}{P_f}$

$$Q_T = P_iV_i\,ln\left(\frac{P_i}{P_f}\right)$$

$$Q_T = 1.4 \times 1.01 \times 10^5 \times 3.5 \times 10^{-3} \times ln\left(\frac{1.4}{0.6}\right) = 419.3\ \text{J}$$

Q15.

0.586 moles of Helium gas is filled in a spherical balloon of diameter 30.0 cm at a pressure of 1.00 atm. What is the rms speed of the helium atoms? [$M_{He} = 4.00\times10^{-3}$ kg/mole]

A) 1.35 km/s
B) 1.00 km/s
C) 2.05 km/s
D) 2.11 km/s
E) 5.01 km/s

Ans:

$$V_{rms} = \sqrt{\frac{3RT}{M}};\, T = \frac{PV}{nR} = \frac{1.01 \times 10^5 \times \frac{4\pi}{3}(0.15)^3}{0.586 \times 8.314} = 293.1\ \text{K}$$

$$= \sqrt{\frac{3 \times 8.314 \times 293.1}{4 \times 10^{-3}}} = 1351.9\,\frac{m}{s} = 1.35\ \text{km/s}$$

Q16.

An ideal diatomic gas undergoes an adiabatic process in which its pressure increases from 1.00 atm to 20.0 atm. What is the ratio of the final volume to the initial volume of the gas (V_f/V_i)?

A) 0.118
B) 0.512
C) 0
D) 2.12
E) 4.21

Ans:

$$P_i V_i^{\gamma} = P_f V_f^{\gamma} \Rightarrow \frac{V_f}{V_i} = \left(\frac{P_i}{P_f}\right)^{\frac{1}{\gamma}} == \left(\frac{1}{20}\right)^{\frac{5}{7}} = 0.1177$$

Q17.

For which of the following process in a closed system, the change in entropy is zero:

A) reversible adiabatic process
B) free expansion process
C) irreversible isothermal process
D) irreversible isobaric process
E) irreversible isochoric (isovolumetric) process

Ans:

A

Q18.

A freezer holds 1.25 moles of air at 25.0 °C and 1.00 atm. The air is then cooled to −18.0 °C. What would be the entropy change of air if the pressure were maintained at 1.00 atm during the cooling? [Assume air behaves like an ideal diatomic gas]

A) – 5.67 J/K
B) – 3.89 J/K
C) + 1.69 J/K
D) + 4.62 J/K
E) – 8.89 J/K

Ans:

$$\Delta S = nR\,ln\left(\frac{V_f}{V_i}\right) = nC_v\,ln\left(\frac{T_f}{T_i}\right)$$

For isobaric process $\frac{V_f}{V_i} = \frac{T_f}{T_i}$

$$\Delta S = nR\,ln\left(\frac{T_f}{T_i}\right) + nC_v\,ln\left(\frac{T_f}{T_i}\right) = n(R + C_v)n\left(\frac{T_f}{T_i}\right)$$

$$\Delta S = n\left(R + \frac{5}{2}R\right) + ln\left(\frac{T_f}{T_i}\right) = n\frac{7}{2}R\,ln\left(\frac{T_f}{T_i}\right)$$

$$\Delta S = 1.25 \times \frac{7}{2} \times 8.314 \times ln\left(\frac{273 - 18}{27 + 25}\right) = 36.4 \times ln(0.856)$$

$$\Delta S = 36.4 \times ln(0.856) = -5.67\ \text{J/K}$$

Q19.

A Carnot heat engine has an efficiency of 22.0 %. It operates between constant-temperature reservoirs differing in temperature by 75.0 C°. What is the temperature of the lower temperature reservoir?

A) 266 K
B) 348 K
C) 109 K
D) 301 K
E) 125 K

Ans:

$$\epsilon_c = \frac{T_H - T_L}{T_H} = \frac{\Delta T}{T_H} \Rightarrow T_H = \frac{\Delta T}{\epsilon_c}$$

$$T_H = \frac{75}{0.22} = 341$$

$$T_L = T_H - \Delta T = 341 - 75 = 266\ \text{K}$$

Q20.

A refrigerator converts 7.0 kg of water at 0 °C into ice at 0 °C in one hour. What is the coefficient of performance of the refrigerator if its power input is 3.0×10^2 W?

A) 2.2
B) 1.2
C) 3.5
D) 1.0
E) 4.7

Ans:

$$K = \frac{Q_L}{W}; \quad Q_L = mL_F; \; W = P \times t$$

$$K = \frac{Q_L}{W} = \frac{7 \times 333 \times 10^3}{300 \times 3600} = 2.2$$