Q1.

A string of 80.0 cm length is fixed at both ends. The string oscillates in the fundamental mode with a frequency of 60.0 Hz and a maximum amplitude of 0.20 cm of the standing wave. What is the maximum transverse speed of a particle oscillating on the string at x = 20.0 cm?

A) 53.3 cm/s
B) 59.8 cm/s
C) 77.5 cm/s
D) 35.1 cm/s
E) 44.7 cm/s

Ans:

$$|u_{max}| = |2\omega y_m sin(kx)|$$

$$\frac{\lambda}{2} = L \Longrightarrow \lambda = (2)(0.8) = 1.6\, m$$

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

$$\Longrightarrow |u_{max}| = (120\pi)(0.2) sin\left(\left(\frac{2\pi}{1.6}\right)(0.2)\right) = 53.3\ cm/s$$

Q2.

A horizontal wire is stretched with a tension of 94.0 N, and the speed of transverse waves for the wire is 492 m/s. What must the amplitude of a traveling wave of frequency 69.0 Hz be in order for the average power carried by the wave to be 0.365 W.

A) 4.51 mm
B) 5.32 mm
C) 3.76 mm
D) 7.54 mm
E) 5.98 mm

Ans:

$$P_{avg} = \frac{1}{2}\mu\omega^2 y_m^2$$

$$0.365 = \frac{1}{2}\frac{\tau}{v^2} v (2\pi f)^2 y_m^2$$

$$y_m = 0.00451\, m = 4.51\, mm$$

Q3.

Two sinusoidal waves, identical except for phase, travel in the same direction along a stretched string, producing a resultant wave $y(x,t) = 0.097 \sin(15x - 2.4t + 0.78)$, where x is in meters and t is in seconds. What is the amplitude of the interfering waves?

A) 0.068 m
B) 0.052 m
C) 0.097 m
D) 0.035 m
E) 0.044 m

Ans:

$$y'_m = 2y_m cos\left(\frac{\Phi}{2}\right) sin\left(kx - \omega t + \frac{\Phi}{2}\right)$$

$$\frac{\Phi}{2} = 0.78\, rad \Rightarrow cos\frac{\Phi}{2} = 0.71$$

$$y_m = \frac{0.097}{(2)(0.71)} = 0.068\, m$$

Q4.

A light string is fixed between two supports with two successive standing-wave frequencies occur at 525 Hz and 630 Hz. There are other standing-wave frequencies lower than 525 Hz and higher than 630 Hz. If the speed of transverse waves on the string is 384 m/s, then find the length of the string?

A) 1.83 m
B) 1.22 m
C) 1.12 m
D) 2.86 m
E) 2.12 m

Ans:

$$f_1 = 630 - 525 = 105\, Hz$$

$$f_1 = \frac{(1)V}{2\, L} = \frac{384}{2L} = 105\, Hz$$

$$\Longrightarrow L = 1.83\, m$$

Q5.

Five organ pipes are described below. Which one has the highest fundamental frequency?

A) A 1.6-m pipe with both ends open
B) A 3.3-m pipe with one end open and the other closed
C) A 2.3-m pipe with one end open and the other closed
D) A 3.0-m pipe with both ends open
E) A pipe in which the displacement nodes are 5 m apart

Ans:

$$f = \frac{v}{2L} = \frac{343}{(2)(1.6)} = 107\ Hz\ \ which\ is\ laragest\ of\ all$$

Q6.

As you stand by the side of the road, a car approaches you at constant speed, sounding its horn, and you hear a frequency of 120 Hz. After the car has passed, you hear a frequency of 100 Hz. If the speed of sound in air is 343 m/s, then find the speed of the car.

A) 31.2 m/s
B) 68.6 m/s
C) 25.1 m/s
D) 23.3 m/s
E) 21.0 m/s

Ans:

$$f_{ap} = f\left(\frac{v}{v - v_c}\right) \Longrightarrow 120 = f\ \frac{343}{343 - v_c} \longrightarrow (1)$$

$$f_{pa} = f\left(\frac{v}{v + v_c}\right) \Longrightarrow 100 = f\ \frac{343}{343 + v_c} \longrightarrow (2)$$

$$\Longrightarrow \frac{(1)}{(2)} \Longrightarrow 1.2 = \frac{343 + v_c}{343 - v_c} \Longrightarrow v_c = 31.2\ m/s$$

Q7.

At point *A*, 3.0 m from a small point source of sound that is emitting uniformly in all directions, the sound intensity level is 53 dB. How far from the source must you go so that the intensity is one-fourth of what it was at *A*?

A) 6.0 m
B) 4.0 m
C) 9.0 m
D) 12 m
E) 24 m

Ans:

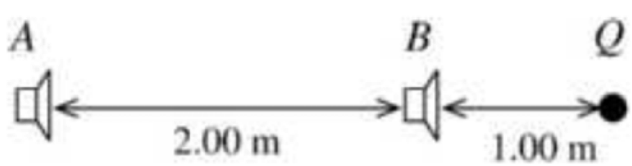
$$\frac{I_2}{I_1} = \frac{1}{4} = \frac{\frac{P_s}{4\pi r_2^2}}{\frac{P_s}{4\pi r_1^2}} = \frac{r_1^2}{r_2^2}$$

$$\sqrt{\frac{1}{4}} = \frac{r_1}{r_2} \Rightarrow \frac{1}{2} = \frac{r_1}{r_2} \Rightarrow r_2 = 6\ m$$

Q8.

Figure 1 shows two loudspeakers, *A* and *B* are driven by the same amplifier and emit sinusoidal sound waves in phase. Point *Q* along the extension of the line connecting the speakers. Find the ratio of the lowest frequency for which constructive interference occurs at *Q* relative to the lowest frequency for which destructive interference occurs at the same point *Q*.

Figure 1



A) 2.00
B) 1.00
C) 3.00
D) 1.50
E) 1.20

Ans:

$$For\ contructive\ interference\ \Delta L = \lambda = 1\ m$$

$$v = f\lambda \longrightarrow f_c = 343\ Hz$$

$$For\ destructive\ \ interference\ \Delta L = \frac{\lambda}{2} = 1 \ \Rightarrow \lambda = 2m$$

$$f_d = \frac{343}{2}\ Hz$$

$$\Rightarrow \frac{f_c}{f_d} = 2$$

Q9.

Organ pipe *A*, with one open end and the other end closed, has a fundamental frequency of 190 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 = 343 m/s]

A) 0.903 m
B) 0.816 m
C) 0.785 m
D) 0.568 m
E) 0.855 m

Ans:

$$f_{3B} = f_{3A}$$

$$\frac{3V}{2L_B} = \frac{3V}{4L_A} \Longrightarrow L_B = 2L_A = 0.903\, m$$

$$L_A = \frac{v}{4L_A} \Longrightarrow L_A = \frac{343}{(4)(190)} = \frac{343}{760}$$

Q10.

A system undergoes an adiabatic process in which its internal energy increases by 20 J. Only one of the following statements is CORRECT.

A) 20 J of work was done on the system
B) 20 J of work was done by the system
C) the system received 20 J of energy as heat
D) the system lost 20 J of energy as heat
E) 40 J of work was done by the system and 20 J of heat lost from the system

Ans:

$$\Delta E = Q - W$$

$$+20J = 0 - W$$

$$\Longrightarrow W = -20\, J\ work\ done\ on\ system$$

Q11.

A glass container whose volume is 1000 cm^3 at 0.00 °C is completely filled with mercury at this temperature. When the container and mercury are warmed to 55.0 °C, a volume of 8.95 cm^3 of mercury overflow. If the coefficient of volume expansion of mercury is 18.0×10^{-5} K^{-1}, find the coefficient of volume expansion of the glass.

A) 1.73×10^{-5} °C^{-1}
B) 1.20×10^{-5} °C^{-1}
C) 2.65×10^{-5} °C^{-1}
D) 1.00×10^{-5} °C^{-1}
E) 2.15×10^{-5} °C^{-1}

Ans:

$$\Delta V = \Delta V_{Hg} - \Delta V_{glass}$$

$$8.95 = (\beta V \Delta T)_{Hg} - (\beta V \Delta T)_{g}$$

$$\beta_{Hg} = 1.727 \times 10^{-5} °C^{-1}$$

Q12.

A 5.00-kg block of ice at 0°C is added to an insulated container partially filled with 10.0 kg of water at 15.0°C. Neglecting the heat capacity of the container, find the mass of ice that was melted when thermal equilibrium is reached.

A) 1.89 kg
B) 3.11 kg
C) 4.21 kg
D) 1.11 kg
E) 3.89 kg

Ans:

$$Q = m l_f$$

$$(10)(4190)(15) = m(333 \times 10^3)$$

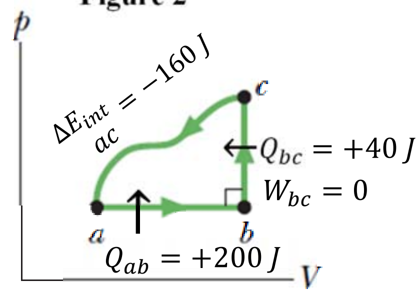
$$\Longrightarrow m = 1.89\ kg$$

Q13.

Figure 2 shows a closed cycle for a gas. The change in internal energy along path *ca* is –160 J. The energy transferred to the gas as heat is 200 J along path *ab* and 40 J along path *bc*. How much work is done by the gas along path *ab*?

A) +80 J
B) 0
C) +20 J
D) –20 J
E) +40 J

Figure 2



Ans:

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

$$+160 = 240 - (W_{ab} + \cancelto{0}{W_{ab}})$$

$$\Rightarrow W_{ab} = +80\ J$$

Q14.

Figure 3 shows the *pV*-diagram for an isothermal expansion of 1.50 mol of an ideal gas, at a temperature of 15.0°C. Find the heat absorbed (or released) by the gas during the expansion.

A) $+2.49 \times 10^3$ J
B) -2.49×10^3 J
C) $+1.14 \times 10^3$ J
D) $+3.22 \times 10^3$ J
E) -3.22×10^3 J

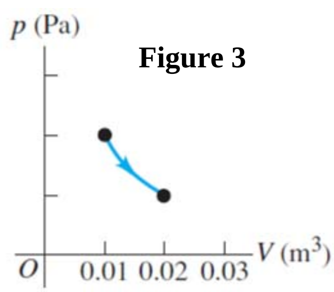


Figure 3

Ans:

$$Q = W = nRT ln\left(\frac{V_f}{V_i}\right)$$

$$= (1.5)(8.31)(15 + 273.15) ln\left(\frac{0.02}{0.01}\right)$$

$$= +2.49 \times 10^3\ J$$

Q15.

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

A) 0.45
B) 2.2
C) 0.25
D) 5.0
E) 1.0

Ans:

$$\frac{(v_{rms})_{Ar}}{(v_{rms})_{H_2}} = \frac{\sqrt{\frac{3R(T)}{40}}}{\sqrt{\frac{3RT}{2}}} = 0.45$$

Q16.

Two moles of a monatomic ideal gas are at initial temperature of 100 K. The gas expands adiabatically and does 599 J of work. Find the final temperature of the gas?

A) 76.0 K
B) 124 K
C) 157 K
D) 24.0 K
E) 32.0 K

Ans:

$$\Delta E_{int} = \cancelto{0}{Q_0} - W$$

$$nC_V \Delta T = -599$$

$$\frac{3}{2} nR\Delta T = -599 \Longrightarrow T_f = 76\ K$$

Q17.

Initially, 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. Find the magnitude of the change in internal energy of the gas due to this process.

A) 1.16×10^3 J
B) 1.98×10^3 J
C) 2.11×10^3 J
D) 2.96×10^3 J
E) 2.55×10^3 J

Ans:

$$n = \frac{PV}{RT} = 0.17$$

$$T_i {V_i}^{\gamma-1} = T_f {V_f}^{\gamma-1}$$

$$\Rightarrow T_f = 629\ K$$

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

$$\Delta E_{int} = (0.17)\left(\frac{5}{2}\right)(8.31)(629 - 300) = 1.16 \times 10^3\ J$$

Q18.

An ideal monatomic gas contains 4.50 moles. The pressure of the gas is doubled at constant volume. How much is the change in the entropy of the gas?

A) +38.9 J/K
B) –38.9 J/K
C) +49.2 J/K
D) –49.2 J/K
E) 0

Ans:

$$\frac{T_f}{T_i} = \frac{P_f}{P_i} = 2$$

$$\Delta S = nc_v ln\left(\frac{T_f}{T_i}\right)$$

$$\Delta S = (4.5)\left(\frac{3}{2}\right)(8.31) ln 2 = +38.9\ J/K$$

Q19.

An ideal engine absorbs heat at 527 °C and rejects heat at 127 °C. If the engine delivers 25.0 Watts of power, how much heat it absorbs in one hour?

A) 1.8×10^5 J
B) 3.0×10^4 J
C) 9.0×10^4 J
D) 5.9×10^5 J
E) 2.5×10^5 J

Ans:

$$\varepsilon_c = 1 - \frac{(127+273)}{(527+273)} = 1 - \frac{400}{800} = 0.5$$

$$\Rightarrow 0.5 = 1 - \frac{25}{Q_H} \Rightarrow Q_H = 50\,J \implies in\ 1\ hour$$

$$Q_{3600s} = 1.8 \times 10^5\,J$$

Q20.

An inventor claims to have a heat engine that has efficiency of 40% when it operates between a high temperature reservoir of 150 ºC and a low temperature reservoir of 30 ºC. Only one of the following statements is CORRECT regarding the inventor claim.

A) It violates the second law of thermodynamics
B) It violates the first law of thermodynamics
C) It violates the zeroth law of thermodynamics
D) It violates both the zeroth and first laws of thermodynamics
E) Does not necessarily violate any of the laws of thermodynamics

Ans:

$$\varepsilon = 1 - \frac{30+273}{150+273} = 0.3$$

$$30\% < 40\%$$
