Q1.

A transverse traveling wave is described by $y = 0.15 \sin\left[\frac{\pi}{16}(2x - 64t)\right]$, where y and x are in meter and t is in second. Determine the first positive x-coordinate where y is maximum and when $t = 0$.

A) 4.0 m
B) 8.0 m
C) 16 m
D) 2.0 m
E) 13 m

Ans:

$$0.15 = 0.15\sin\left(\frac{\pi}{16}(2\mathrm{x})\right) = 0.15\sin\left(\frac{\pi}{8}\,\mathrm{x}\right)$$

$$\Longrightarrow \left(\frac{\pi}{8}\,\mathrm{x}\right) = \frac{\pi}{2} \;\Rightarrow x = 4.0\ \mathrm{m}$$

Q2.

A resultant traveling wave can be produced by an interference between two sinusoidal waves of the same frequency and amplitude. This interference is fully destructive only if the two waves:

A) travel in the same direction and are 180° out of phase
B) travel in opposite directions and are 180° out of phase
C) travel in the same direction and are in phase
D) travel in opposite directions and are in phase
E) travel in the same direction and are 90° out of phase

Ans:

A

Q3.

A traveling sinusoidal wave is generated on a stretched string. The string has a linear mass density μ = 0.20 kg/m and is stretched under a tension of 400 N. If the traveling wave has an amplitude of 30 cm and a period of 1.4 s, how much average power is transmitted by this wave?

A) 8.1 W
B) 1.5 W
C) 33 W
D) 40 W
E) 2.4 W

Ans:

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

$$v = \sqrt{\frac{t}{\mu}} = \sqrt{\frac{400}{0.2}}$$

$$v = 44.7\ \mathrm{m/s}$$

$$T = 1.4 = \frac{1}{f}$$

$$\omega = 2\pi f = \frac{2\pi}{1.4} = 4.5\ \mathrm{rad/s}$$

$$P_{avg} = \frac{1}{2}(0.2)(44.7)(4.5)^2(0.3)^2 = 8.1\ \mathrm{W}$$

Q4.

A string with a linear mass density of 0.0350 kg/m and a mass of 0.0140 kg is clamped at both ends. Under what tension in the string will it have a standing wave with a fundamental frequency of 110 Hz?

A) 271 N
B) 312 N
C) 455 N
D) 583 N
E) 691 N

Ans:

$$f_n = \frac{n}{2L} v = \frac{n}{2L}\sqrt{\frac{\tau}{\mu}} \quad n = 1, 2, 3 \ldots$$

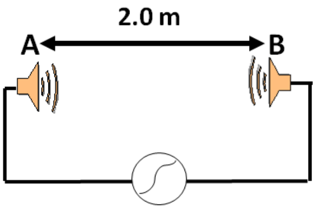
$$\mu = \frac{m}{L} \Rightarrow L = \frac{m}{\mu} = \frac{0.014}{0.035}$$

$$n = 1 \Rightarrow f_1 = \frac{1}{2L}\sqrt{\frac{\tau}{\mu}} \Rightarrow \tau = 4L^2 f_1{}^2 \mu \Rightarrow \tau = 271\ \mathrm{N}$$

Q5.

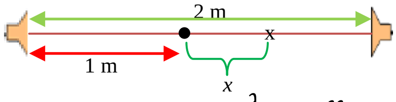
In Figure 1, two identical speakers, separated by 2.00 m, are connected (in phase) to the same sound source. An observer, initially at the midpoint between the two speakers, moves slowly toward B along the line joining the two speakers. He hears the first minimum in sound after moving a distance of 0.100 m. Find the frequency of the sound waves. [The speed of sound in air = 344 m/s]

Figure 1



A) 860 Hz
B) 116 Hz
C) 1720 Hz
D) 581 Hz
E) 172 Hz

Ans:



$$\Delta \mathrm{L} = (1 + x) - (1 - x) = 2x = \frac{\lambda}{2} = \frac{v}{2f}$$

$$f = \frac{v}{4x} = \frac{344}{0.4} = 860\ Hz$$

Q6.

A jet plane has a sound level β_{jet} =120 dB while the sound level of a child is β_{child} = 20 dB. Their corresponding sound intensities ratio (I_{jet}/I_{child}) is:

A) 10^{10}
B) 10^{8}
C) 10^{6}
D) 10^{12}
E) 10^{11}

Ans:

$$\beta_1 = 10 \log \frac{I_1}{I_0} \quad ; \quad \beta_2 = 10 \log \frac{I_2}{J_0}$$

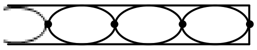
$$\beta_2 - \beta_1 = 10 \log \frac{I_2}{I_1} \Rightarrow \frac{\beta_2 - \beta_1}{10} = \log \frac{I_2}{I_1}$$

$$\frac{I_2}{I_1} = 10^{\frac{100}{10}} = 10^{10}$$

Q7.

Standing waves with the seventh harmonic are produced in a long pipe closed at one end. The number of antinodes in the standing wave pattern is:

A) 4
B) 3
C) 2
D) 5
E) 6



Ans:

A

Q8.

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. What is the speed of the car? Assume that the speed of sound in air is 341 m/s.

A) 31.0 m/s
B) 25.0 m/s
C) 23.0 m/s
D) 41.0 m/s
E) 47.0 m/s

Ans:

$$f' = f\,\frac{v}{v - v_s}$$

$$f'' = f\,\frac{v}{v + v_s}$$

$$\frac{f'}{f''} = \frac{v + v_s}{v - v_s}$$

$$1.2 = \frac{v + v_s}{v - v_s} \Rightarrow 1.2\,(v - v_s) = (v + v_s)$$

$$0.2\,v = 2.2\,v_s \;\Rightarrow v_s = 31\ m/s$$

Q9.

Given two metal rods A and B. The length of rod A is twice that of rod B, whereas the coefficient of linear thermal expansion for rod B is three times that of rod A. If rod A undergoes a change of temperature that is three times larger than that of rod B, which of the following statements is TRUE?

A) The change in the length of rod A is twice that of rod B.
B) The change in the length of rod B is twice that of rod A.
C) The change in the length of rod A is six times larger than that of rod B.
D) The change in the length of rod B is six times larger than that of rod A.
E) The change in the length of rod A is the same as that of rod B.

Ans:

$$\Delta L_A = \alpha_A L_A \Delta T_A$$

$$\Delta L_B = \alpha_B L_B \Delta T_B$$

$$\Delta L_B = \cancel{3}\alpha_A \frac{L_A}{2}\frac{\Delta T_A}{\cancel{3}}$$

$$= \alpha_A \frac{L_A \Delta T_A}{2}$$

$$= \frac{\Delta L_A}{2}$$

$$\Delta L_A = 2\Delta L_B$$

Q10.

The specific heat of object B is twice that of object A, and the mass of object A is three times the mass of object B. Initially A is at 300 K and B is at 450 K. They are placed in thermal contact with each other and the combination is isolated. The final temperature of both objects is:

A) 360 K
B) 340 K
C) 250 K
D) 420 K
E) 460 K

Ans:

$$m_A c_A \Delta T_A = m_B c_B \Delta T_B$$

$$3\cancel{m_B}\cancel{c_A}(T_f - T_A) = \cancel{m_B}2\cancel{c_A}(T_B - T_f)$$

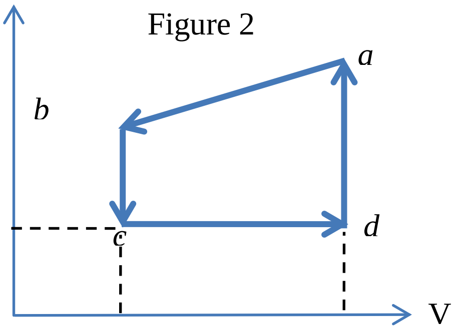
$$3T_f - 3T_A = 2T_B - 2T_f$$

$$5T_f = 2T_B + 3\,T_A \Rightarrow T_f = \frac{3\,T_A + 2T_B}{5} = 360\text{ K}$$

Q11.

The change in the internal energy of a gas as it moves from *a* to *c* along the path *abc* is -300 J (Figure 2). As it moves from *c* to *d*, 280 J is transferred to it as heat. And as the gas moves from *d* to *a* it absorbs 110 J as heat. How much work is done on the gas as it moves from *c* to *d*?

Figure 2



A) + 90 J
B) – 90 J
C) + 260 J
D) – 260 J
E) 0 J

Ans:

$\Delta E_{abc} = -300$ J

$Q_{cd} = 280$ J

$Q_{da} = 110$ J

$Q_{cda} = Q_{cd} + Q_{da} = 390$ J

$\Delta E_{cda} = -\Delta E_{abc} = 300$ J

$\Delta E_{cda} = Q_{cda} - W_{cda} = 390 - W_{cda} = 300$ J

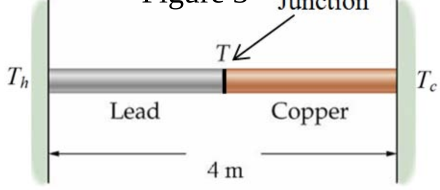
$W_{cda} = W_{cd} + \cancelto{0}{W_{da}} = 390 - 300 = 90$ J

$W_{cd} = 90$ J

Q12.

Two rods, made of lead and copper, of equal lengths and diameters are attached to each other as shown in Figure 3. The rods are placed between hot and cold reservoirs with temperatures T_h = 350 °C and T_c = 10.0 °C. Find the temperature T at the junction between the two rods. (Given k_{lead} = *35.0 W/m.K*, and k_{copper} = *401 W/m.K*)

Figure 3



A) 37.3 °C
B) 63.4 °C
C) 21.2 °C
D) 42.1 °C
E) 73.5 °C

Ans:

$$\frac{Q}{t} = \frac{kA(T_H - T_C)}{L}$$

$$\frac{35\cancel{A}(350 - T)}{\cancel{L}} = \frac{401\cancel{A}(T - 10)}{\cancel{L}}$$

$35(350 - T) = 401(T - 10)$

$12250 - 35\,T = 401\,T - 4010 \Rightarrow T = 37.3\,°C$

Q13.

If the pressure of an ideal gas is tripled in an isothermal process, the root-mean-square speed of the molecules:

A) does not change
B) increases by a factor of $\sqrt{3}$
C) decreases by a factor of $\sqrt{3}$
D) increases by a factor of 2
E) decreases by a factor of 2

Ans:

$$v_{rms} = \sqrt{\frac{3RT}{M}} \quad ; \quad \text{Isothermal} \Rightarrow T = \text{constant}$$

Q14.

The temperature of 5.00 moles of an ideal monatomic gas is raised by 25.0 K in an adiabatic process. The work done in this process is:

A) −1.56 kJ
B) +3.45 kJ
C) −2.53 kJ
D) +5.53 kJ
E) +12.0 J

Ans:

adiabatic process $Q = 0$; $\quad \Delta E = \cancel{Q}^{\,0} - W = -W$

$W = -\Delta E = -nc_v\Delta T = -n\frac{3}{2}R\Delta T$

$= -5 \times \frac{3}{2} \times 8.31 \times (+25) = -1.56\ \text{kJ}$

Q15.

A 4.50 moles of an ideal gas undergoes isothermal compression from an initial volume of 5.00 m^3 to a final volume of 2.00 m^3. The amount of heat transferred from the gas to its environment during this process is 9.83 kJ. Find the temperature of the gas.

A) 287 K
B) 201 K
C) 154 K
D) 305 K
E) 273 K

Ans:

Isothermal Process $\Delta E = 0$

$\Delta E = Q - W = 0 \Rightarrow Q = W$

$$W = nRT\,ln\left(\frac{v_f}{v_i}\right) = Q \Rightarrow T = \frac{W}{nR\,ln(v_f/v_i)}$$

$$T = -\frac{9830}{4.5 \times 8.31 \times ln\,(2/5)} = 287\ \text{K}$$

Q16.

An ideal gas has an initial temperature of 200 K, and a volume of 2.0 liters. If the volume of the gas is reduced to 1.0 liter at constant pressure, find the new average kinetic energy per molecule.

A) 2.1×10^{-21} J
B) 4.2×10^{-21} J
C) 1.1×10^{-21} J
D) 3.6×10^{-21} J
E) 8.7×10^{-21} J

Ans:

$$k_i = \frac{3}{2} k_B T_i$$

$$k_f = \frac{3}{2} k_B T_f$$

$$\frac{PV_i}{PV_f} = \frac{nRT_i}{nRT_f}$$

$$T_f = T_i \frac{V_f}{V_i} = 100 \text{ K}$$

$$k_f = \frac{3}{2} \times 1.38 \times 10^{-23} \times 100$$

$$k_f = 2.1 \times 10^{-21} \text{J}$$

Q17.

An ideal heat engine absorbs heat from a reservoir at 527 °C and rejects heat to a reservoir at 127 °C. What is the power produced by the engine if the rate at which heat is absorbed is
1500 W?

A) 750 W
B) 680 W
C) 450 W
D) 940 W
E) 230 W

Ans:

$$\frac{\frac{Q_L}{t}}{T_L} = \frac{\frac{Q_H}{t}}{T_H}$$

$$\frac{Q_L}{t} = \frac{T_L}{T_H}\frac{Q_H}{t} = \frac{400}{800} \times 1500$$

$$= 750 \text{ W}$$

Q18.

When ice, initially at 0.00 ^oC, is heated to 40.0 ^oC, its entropy is increased by 1.18 kJ/K. Find the mass of ice.

A) 658 g
B) 472 g
C) 234 g
D) 961 g
E) 501 g

Ans:

$$\Delta S = m\frac{L_f}{T} + mcLn\left(\frac{T_f}{T_i}\right)$$

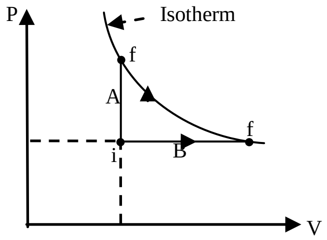
$$\Delta S = m\left[\frac{L_f}{T} + cLn\left(\frac{T_f}{T_i}\right)\right] \Rightarrow m = \frac{1180}{\frac{333\times 10^5}{273} + 4190Ln\left(\frac{313}{273}\right)} = 658\text{ g}$$

$$\Rightarrow m = 0.658\text{ kg}$$

Q19.

A monatomic gas can be taken through one of the two thermodynamical processes A or B. Process A is at constant volume and process B is at constant pressure. Both processes are shown in a PV diagram in Figure 4. The change in entropy:

Figure 4



A) is greater for process B than for process A
B) is greater for process A than for process B
C) is the same for both processes A and B
D) is greater for process A than for process B only if the initial temperature is low
E) is greater for process A than for process B only if the initial temperature is high

Ans:

isobaric (B)

$$\Delta s_p = nc_pLn\left(\frac{T_f}{T_i}\right)$$

isochoric (A)

$$\Delta s_v = nc_vLn\left(\frac{T_f}{T_i}\right)$$

Both process have same T_i and T_f $C_p > C_v \Rightarrow \Delta s_p > \Delta s_v$

Q20.

A refrigerator rejects 35.0 kJ of heat to the room during each cycle and operates with coefficient of performance of 4.60. What is the work done per cycle?

A) 6.25 kJ
B) 7.61 kJ
C) 0.131 kJ
D) 10.2 kJ
E) 161 kJ

Ans:

$$K = \frac{Q_L}{W} = \frac{Q_H - W}{W} \Rightarrow KW = Q_H - W$$

$$W(K+1) = Q_H \Rightarrow W = \frac{Q_H}{W+1} = \frac{35000}{5.6}$$

$$W = 6250 \text{ J}$$