Q1. A 3.60 m long stretched string has a mass of 0.180 kg. What average power must be supplied to the string to generate a sinusoidal wave having amplitude of 0.100 m, a wavelength of 0.500 m, and traveling with a speed of 30.0 m/s?

A) 1.07 kW
B) 2.13 kW
C) 27.0 kW
D) 4.26 kW
E) 3.20 kW

Ans:

$$P_{avg} = \frac{1}{2}\mu v \omega^2 y_m^2 = \frac{1}{2}\frac{m}{L} v \left(2\pi \frac{v}{\lambda}\right)^2 y_m^2 = 2\pi^2 \frac{m y_m^2 v^3}{L\lambda^2}$$

$$= 2\pi^2 \frac{(0.180\ \text{kg})(0.100\ m)^2 \left(30.0\frac{\text{m}}{\text{s}}\right)^3}{(3.60\ \text{m})(0.500\ \text{m})^2} = 1.07 \times 10^3\ \text{W}$$

Q2.

Two transverse sinusoidal waves, traveling on a string, are described by the wave functions

$$y_1(x,t) = 3.00 \sin\left[\pi(x + 0.600\, t)\right]$$
$$y_2(x,t) = 3.00 \sin\left[\pi(x - 0.600\, t)\right]$$

where x, y_1, and y_2 are in centimeters and t is in seconds. Determine the maximum transverse position of an element of the string at x = 0.250 cm.

A) 4.24 cm
B) 2.12 cm
C) 6.00 cm
D) 2.40 cm
E) 12.0 cm

Ans:

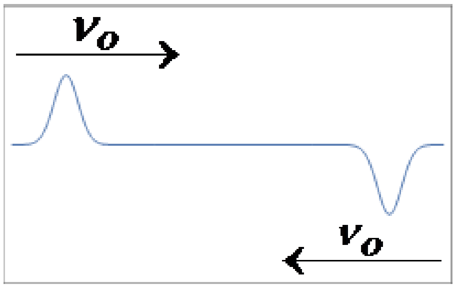
$y'_m = 2\, y_m \sin(\pi\, x) \cos(w\, t)$, for maximum take $\text{Cos}(w\, t) = 1$

$$y'_m = 2y_m \sin kx = 2(3.00\ \text{cm}) \sin \pi(0.250\ \text{m}) = 4.24\ \text{cm.}$$

Q3.

Figure 1 shows two pulses, with equal but inverted amplitude, traveling on the same string toward each other. When the two pulses meet, they will

Figure 1



A) Interfere destructively and then move away without changing the travel of each other
B) Interfere destructively and then disappear
C) Interfere constructively and then move away without changing the travel of each other
D) Interfere constructively and then move as one large pulse
E) Interfere constructively and then disappear

Ans:

A

Q4. A transverse wave is described by the wave function

$$y(x,t) = 10.0\sin(2.00\,x + 5.00\,t)$$

where y and x are in meters and t is in seconds. The ratio of the transverse speed to the wave speed (u/v) at $x = 0$ and $t = 0$ is:

A) 20.0
B) zero
C) 50.0
D) 10.0
E) 100

Ans:

$$y(x,t) = y_m \sin(k\,x + \omega\,t),\;\; u = \frac{dy(x,t)}{dt} = y_m\omega\cos(k\,x+\omega\,t),\;\text{and}\;\; v = \frac{\omega}{k}$$

$$\frac{u|_{x=t=0}}{v} = \frac{y_m\omega\cos(k\,x+\omega\,t)|_{x=t=0}}{\frac{\omega}{k}} = ky_m = 2\times10 = 20$$

Q5.

A car with speed v_{car} and a bus with speed v_{bus} are heading straight toward each other, with v_{car} = 1.20 v_{bus}. The horn of the bus, with frequency f_{bus} =2400 Hz, is blowing and is heard to have a frequency of 3000 Hz by the driver in the car. Find the speed of the bus, in m/s, if the speed of sound is 340 m/s.

A) 34.7
B) 51.2
C) 32.7
D) 27.0
E) 63.1

Ans:

$$f_{car} = f_{bus}\left(\frac{v+v_{car}}{v-v_{bus}}\right) \Rightarrow v_{bus} = v\left(\frac{f_{car}-f_{bus}}{f_{car}+1.2\,f_{bus}}\right) = 340\left(\frac{3000-2400}{3000+1.2\times 2400}\right) = 34.7 \text{ m/s}$$

Another way

$$v_b = v\left(\frac{f_c - f_b}{f_c + 1.2 f_b}\right) = 34.7\ m/s$$

Q6.

A standing wave is set up in an air-filled tube that is closed at one end. The standing wave has four nodes and the frequency of oscillation is 180 Hz. What is the length of the tube? (Speed of sound = 343 m/s)

A) 3.33 m
B) 6.66 m
C) 7.62 m
D) 2.22 m
E) 1.90 m

Ans:

4 Nodes, $L = \frac{3}{2}\lambda + \frac{\lambda}{4} = \frac{7}{4}\lambda = \frac{7}{4}\frac{v}{f} = \frac{7\times 343}{4\times 180} = 3.33 \text{ m}$

Q7.

A point source emits sound wave with power 3.14 μW. What is the sound level in decibels at a distance 2.00 m away?

A) 48.0 dB
B) 34.5 dB
C) 21.5 dB
D) 56.2 dB
E) 40.0 dB

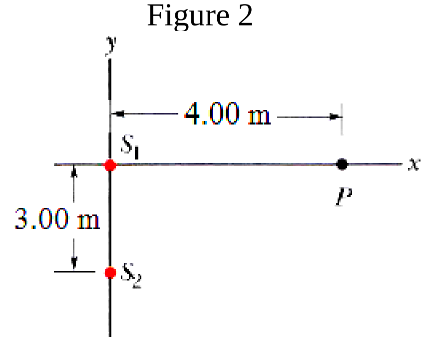
Ans:

$I = P/4\pi r^2 = 3.14 \times 10^{-6}/4\pi\,(2.0)^2 = 6.25 \times 10^{-8}\ W/m^2 \Rightarrow \beta = (10dB)\log(6.26\times10^{-8}/10^{-12}) = 48.0\ dB$

Q8.

Figure 2 shows two identical point sources S_1 and S_2 that emit sound waves, in phase, of frequency 660Hz and speed of 330 m/s. What is the phase difference of the waves at the point *P*?

Figure 2



A) 4 π rad.
B) 2 π rad.
C) π rad.
D) π/2 rad.
E) π/4 rad.

Ans:

$\lambda = v/f = 330/660 = 0.5$ m. Also, $\phi = 2\pi\,(\Delta L/\lambda) = 2\pi\,(5.00 - 4.00)/0.5 = 4\pi$ rad.

Q9.

A steel tank is completely filled to the top with 2.80 m^3 of ethanol when both the tank and the ethanol are at a temperature of 32.0 ^oC. Now, the tank and its contents have been cooled to 18.0 ^oC. Calculate the additional volume of ethanol that can be added to fill the tank to the top. [For the steel $\beta = 3.60\times10^{-5}\ C^{o-1}$, for the ethanol $\beta = 7.50\times10^{-4}\ C^{o-1}$]

A) 28.0 L
B) 15.0 L
C) 34.0 L
D) 20.0 L
E) 17.0 L

Ans:

The volume of the tank is:

$$\Delta V_s = V_0\beta_s\Delta T = (2.80m^3)(3.6\times10^{-5}(°C)^{-1})(-14.0°C)$$

$$= -1.41\times10^{-3}\ m^3 = -1.41\ \text{L}$$

$$The\ volume\ change\ for\ the\ ethanol\ is:$$

$$\Delta V_e = V_0\beta_e\Delta T = (2.80m^3)(75\times10^{-5}(°C)^{-1})(-14.0°C)$$

$$= -2.94\times10^{-2}\ m^3 = -29.4\ \text{L}$$

$$The\ \ empty\ volume\ in\ the\ tank\ is\ \Delta V_e - \Delta V_s = -29.4\ L - (-1.4\ L)$$

$$= -28.0\ L = 28.0\ L$$

Q10.

One end of an insulated metal rod is maintained at 100.0 ^oC and the other end is maintained at 0 ^oC by an ice-water mixture. The rod is 60.0 cm long and has a cross-sectional area of 1.25 cm^2. The heat conducted by the rod melts 8.50 g of ice in 10.0 min. Find the thermal conductivity of the metal.

A) 226 W/m.K
B) 362 W/m.K
C) 103 W/m.K
D) 412 W/m.K
E) 160 W/m.K

Ans:

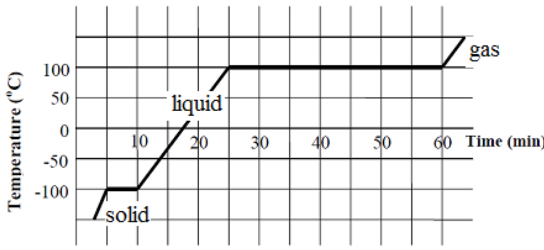
$$P = \frac{Q}{t} = \frac{mL_f}{t} = \frac{2.84\times10^3}{600} = 4.73W$$

$$P = \frac{kA\Delta T}{L} \rightarrow k = \frac{PL}{A\Delta T} = 226\ W/m\cdot K$$

Q11.

When 200 W is supplied continuously to an isolated object of mass 0.400 kg, its phase changes from solid to liquid, and finally to gas as shown in **Figure 3**. What is the latent heat of vaporization, in $\frac{\text{J}}{\text{kg}}$, of the object?

Figure 3



A) 1.05×10^{6}
B) 2.00×10^{6}
C) 1.52×10^{7}
D) 2.35×10^{6}
E) 5.50×10^{6}

Ans:

$$L_v = \frac{Q}{m} = \frac{(60-25)\,\text{min}\,(60\,\text{s/min})\,(200\,\text{J/s})}{(0.4\text{kg})} = 1.05\times10^{6}\,\frac{\text{J}}{\text{kg}}$$

Q12.

Which of the following statements is **true**?

A) $dQ - dW$ represents the change in the internal energy of the system.
B) In any cyclic process, the work done by the gas is zero.
C) In an adiabatic process $Q = W$.
D) At constant volume process the work done by the gas is positive.
E) For the ideal gas $C_p - C_V = R/2$.

Ans:

A

Q13.

The lowest pressure attainable in the laboratory is 5.0×10^{-18} Pa at 20 °C. How many gas molecules are there per m^3 at this pressure?

A) 1.2×10^{3}
B) 2.3×10^{3}
C) 4.4×10^{6}
D) 3.1×10^{5}
E) 5.6×10^{-3}

Ans:

$$PV = nRT = \frac{N}{N_A}RT \quad \Rightarrow \quad \frac{N}{V} = \frac{N_A P}{RT} = \frac{(6.02\times10^{23})(5\times10^{-18}\,\text{Pa})}{(8.31\,\text{J/K})(293\,\text{K})} = 1240/\text{m}^3.$$

Q14.

At 300 K, two moles of an ideal diatomic gas are contained in a cylinder, with a movable piston, of volume 6.0 L. An amount of 5.2 kJ of heat is added to the gas at constant pressure. Calculate the change in the volume, in Liters, of the gas.

A) 1.8
B) 2.3
C) 1.2
D) 3.6
E) 0

Ans:

$$Q = nC_p\Delta T \Rightarrow \Delta T = \frac{Q}{nC_p}, \quad P\Delta V = nR\Delta T \Rightarrow \Delta V = \frac{nR\Delta T}{p} = \frac{nR}{RT_i/V_i}\frac{Q}{nC_p}$$

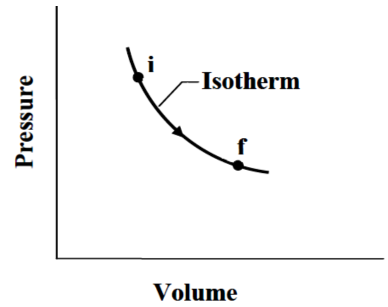
$$\Rightarrow \Delta V = \frac{nR\Delta T}{p} = \frac{nR}{nRT_i/V_i}\frac{Q}{nC_p} = \frac{1}{(300)/6}\frac{5.2\times10^3}{2(7/2)R} = \frac{5.2\times10^3}{7(50)(8.314)} = 1.79\text{ L} = 1.8\text{ L}$$

Q15.

One mole of an ideal gas expands isothermally from state **i** to state **f** as shown in **Figure 4**. At state **i** the volume of the gas is V_0, and the pressure is p_0. At state **f** the volume is $3V_0$. How much heat is added to the gas as it expands from state **i** to state **f**?

A) $p_0V_0\ln 3$
B) $2p_0V_0\ln 3$
C) $p_0V_0\ln 2$
D) $2p_0V_0\ln 2$
E) $(p_0V_0\ln 3)/4$

Figure 4



Ans:

$$W = p_0V_0\int_{V_0}^{3V_0}\frac{dV}{V} = p_0V_0\left[\ln V\right]_{V_0}^{3V_0} = p_0V_0\ln\left(\frac{3V_0}{V_0}\right) = p_0V_0\ln 3$$

$E = N\frac{kT}{2}$. Since T is constant, E is constant. $\underline{\Delta E = 0}$

$Q - W = \Delta E$, so $Q = W + \Delta E$. Since $\Delta E = 0$, $Q = W =$ $Q = W = p_0V_0\ln 3$

Q16.

One liter of a gas, with $\gamma = 1.30$, initially at 21.0 ^{o}C and 1.00 atm, is compressed adiabatically to half of its initial volume. Find its final temperature.

A) 362 K
B) 500 K
C) 25.9 K
D) 300 K
E) 120 K

Ans:

$$T_f = T_i\left(\frac{V_i}{V_f}\right)^{\gamma-1} = (21+273\,\mathrm{K})(1.23) = 362\,\mathrm{K}.$$

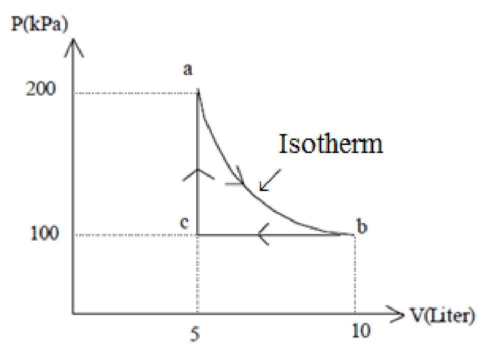
Q17.

A constant amount of an ideal gas undergoes the cyclic process abca in the P-V diagram shown in **Figure 5**. The efficiency of the cycle is 20%. Find the heat added to the gas during the cycle.

A) 966 J
B) 396 J
C) 180 J
D) 300 J
E) 1298 J

Figure 5

Ans:



$$Q_h = \frac{W}{e},$$

$$W = W_{ab} + W_{bc} + W_{ca} = nR\left(T = \frac{P_a V_a}{nR}\right)\ln\left(\frac{V_b}{V_c}\right) + P(V_c - V_b)$$

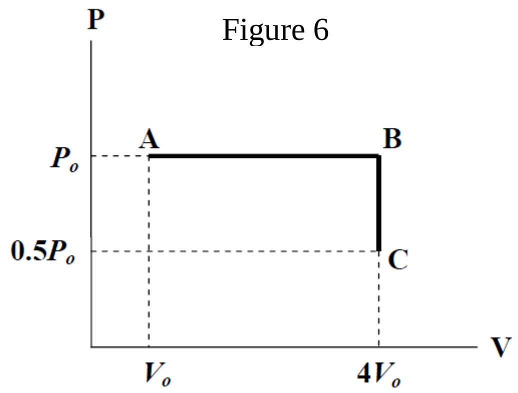
$$= 1000\ln(2) + 100(-5) = 193.14\ \mathrm{J}$$

$$Q_h = \frac{193.14}{0.2} = 965.7\ \mathrm{J}$$

Q18.

Two moles of a monatomic ideal gas are initially at the state A in the PV-diagram of **Figure 6**. The gas is heated and expands at constant pressure to the state B. It is then cooled at constant volume until the pressure has dropped to $0.5P_o$ at the state C. Calculate the change in entropy of the gas in the ABC process.

A) $7R\ln(2)$
B) $5R\ln(2)$
C) $3R\ln(3)/2$
D) $7R\ln(3)$
E) $5R\ln(3)$



Ans:

From the ideal gas law:

$$PV = nRT \Rightarrow T_B = 4T_A; T_c = 2T_A$$

$$\Delta S = C_p \int_A^B \frac{dT}{T} + C_V \int_B^C \frac{dT}{T} = 2C_p \left[\ln T\right]_{T_o}^{4T_o} + 2C_V \left[\ln T\right]_{4T_o}^{2T_o}$$

$$= 2\frac{5}{2}R\ln\left(2^2\right) - 2\frac{3}{2}R\ln\left(2\right) = 10R\ln(2) - 3R\ln(2) = 7R\ln(2)$$

Q19.

A refrigerator, with a coefficient of performance of 4.0, expels 300 J of heat to the surrounding. How much heat is absorbed from inside the refrigerator?

A) 240 J
B) 430 J
C) 120 J
D) 300 J
E) 400 J

Ans:

$$\text{COP(Ref.)} = \frac{Q_c}{W}\frac{Q_c}{Q_h - Q_c} \Rightarrow 4 = \frac{Q_c}{300 - Q_c} \Rightarrow Q_c = 240 \text{ J}$$

Q20.

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

A) If the steam is condensed, its entropy will decrease.
B) The entropy of a system can never decrease.
C) For any closed system $\Delta S < 0$.
D) All the heat engines have efficiencies higher than Carnot's efficiency.
E) The total entropy of a system increases only if it absorbs heat.

Ans:

A
