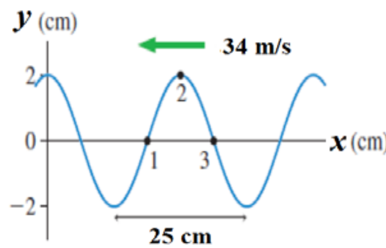
Q1.

Figure 1 shows a graph of a wave traveling to the left along a string at a speed of 34 m/s. At this instant, what is the transverse velocity of points 1, 2, and 3, respectively, on the string?

Figure 1



A) +17 m/s, 0 m/s, −17 m/s
B) −17 m/s, +17 m/s, 0 m/s
C) +17 m/s, −17 m/s, 0 m/s
D) −19 m/s, 0 m/s, +19 m/s
E) +19 m/s, −19 m/s, 0 m/s

Ans:

$$|u_{max}| = \omega y_m = 2\pi f y_m = 2\pi\left(\frac{V}{\lambda}\right) y_m$$

$$= 2\pi \times \frac{34}{0.25} \times 0.02 = 17.09\ m/s$$

Q2.

Two pieces of string, each of length L=1.5 m, are joined together end to end, to make a 3.0 m long combined string. The first piece of string has mass per unit length μ_1=100 g/m, the second piece has mass per unit length $\mu_2 = 6.0\ \mu_1$. If the combined string is under tension $\tau = 5.0$ N, how much time does it take a transverse travelling wave to travel the entire 3.0 m length of the string?

A) 0.73 s
B) 1.1 s
C) 1.7 s
D) 1.9 s
E) 2.8 s

Ans:

$$\tau_{Tot} = L\left(\frac{1}{V_1} + \frac{1}{V_2}\right) = L\left(\sqrt{\frac{\mu_1}{\tau}} + \sqrt{\frac{\mu_2}{\tau}}\right) = 1.5\left[\sqrt{\frac{0.1}{5}} + \sqrt{\frac{0.6}{5}}\right] = 0.731\ s$$

Q3.

Which one of the following transverse waves traveling in the same string transports the maximum power?

A) a wave with velocity 2v, amplitude A/2, and frequency 2f
B) a wave with velocity v, amplitude 2A, and frequency f/2
C) a wave with velocity 2v, amplitude A/2, and frequency f
D) a wave with velocity 2v, amplitude A, and frequency f/2
E) a wave with velocity v, amplitude A, and frequency f

Ans:

A

Q4.

A string oscillates in a third -harmonic standing wave pattern. The amplitude at a point
30 cm from one end of the string is half the maximum amplitude. How long is the string?

A) 5.4 m
B) 4.2 m
C) 6.0 m
D) 6.4 m
E) 7.2 m

Ans:

$$L = \frac{3\lambda}{2}; x = 0.3\ m; k = \frac{2\pi}{\lambda} = 2\pi \times \frac{3}{2L} = \frac{3\pi}{L}$$

$$Amplitude(x = 0.3\ m); \cancel{y_m} = 2\cancel{y_m} sinkx = 2\cancel{y_m} sin\left(\frac{3\pi}{L} \times 0.3\right) = \cancel{y_m}$$

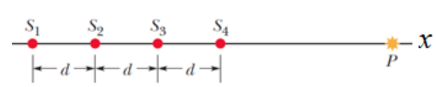
$$1 = 2sin\left(\frac{0.9\pi}{L}\right)$$

$$L = \frac{0.9\pi}{\sin^{-1}\left(\frac{1}{2}\right)} = \frac{0.9\pi}{30°} = \frac{0.9\pi}{\pi/6} = 6 \times 0.9 = 5.4\ m$$

Q5.

Figure 2 shows four isotropic identical in-phase point sound sources S1, S2, S3, and S4 located along x-axis. The sounds from the four sources interfere at point *P,* located on the *x* axis Assume that as the sound waves travel to *P*, the decrease in their amplitude is negligible. If distance $d = \lambda/4$ which of the following statement is **True**.

Figure 2



A) Sound from S1 and S3 interfere destructively at P.
B) Sound from S2 and S4 interfere destructively and from S1 and S3 interfere constructively, at P.
C) Sound from S2 and S4 interfere constructively at P.
D) Sound from S1 and S3 interfere constructively and from S2 and S4 interfere constructively at P.
E) None of the given answers

Ans:

A

Q6.

Standing waves of sound are set up in a vertical tube of length 1.000 m with both ends open, filled with air. The tube has a fundamental frequency $f_{0\text{-}air}$. Then the bottom end of the tube is closed and filled completely with a fluid. The fundamental frequency of the tube filled with the fluid is $f_{0\text{-}fluid}$. Find the fundamental frequency ratio $f_{0\text{-}fluid} / f_{0\text{-}air}$ (speed of sound in air = 343.0 m/s and speed of sound in the fluid is 1482 m/s).

A) 2.160
B) 1.123
C) 1.505
D) 2.789
E) 3.545

Ans:

$$f_{o,air} = \frac{V_{air}}{2L};\ f_{o,fluid} = \frac{V_{fluid}}{4L}$$

$$\frac{f_{o,fluid}}{f_{o,air}} = \frac{V_{fluid}}{2V_{air}} = \frac{1}{2}\left(\frac{1482}{343}\right) = 2.16$$

Q7.

A sound meter placed 3 m from a point isotropic sound source measures a sound level of 70 dB. If the power of the sound source is reduced by a factor of 20, what will be the sound meter reading?

A) 57 dB
B) 11 dB
C) 25 dB
D) 32 dB
E) 66 dB

Ans:

$$\beta_1 - \beta_2 = 10\ log\left(\frac{I_1}{I_2}\right) = 10\ log\left(\frac{P_1}{P_2}\right) = 10\log(20)$$

$$\beta_2 = \beta_1 - 10\log(20) = 70 - 10\log(20) = 70 - 13.01 = \ 56.99\ dB$$

Q8.

A stationary observer is standing between two sound sources A and B. Source A is moving away from the observer, and source B is moving toward the observer. Both sources emit sound of the same frequency. If both sources are moving with a speed $v_{sound}/2$, what is the ratio of the frequencies f_B / f_A detected by the observer?(Assume speed of sound v_{sound} = 343 m/s)

A) 3
B) 4
C) 5
D) 6
E) 7

Ans:

$$f_A = f_0 = \frac{1}{v + \frac{v}{2}} = f_0 \times \frac{2}{3v}$$

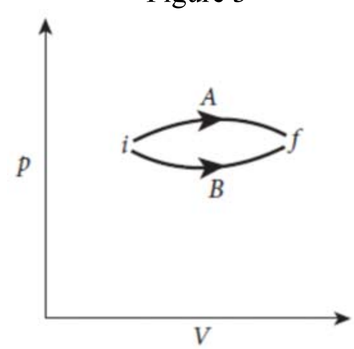
$$f_B = f_0 = \frac{1}{v - \frac{v}{2}} = \frac{2f_0}{v}$$

$$\frac{f_B}{f_A} = \frac{2f_0}{v} \times \frac{3v}{2f_0} = 3$$

Q9.

An ideal gas system can go from state *i* to state *f through process A or B,* as shown in the **Figure 3**. If W_A, W_B, Q_A and Q_B are work done and heat exchanged during processes A and B, respectively, which of the following relations is **True**?

Figure 3



A) $Q_A > Q_B$
B) $Q_A = Q_B$
C) $Q_A < Q_B$
D) $W_A = W_B$
E) $W_B > W_A$

Ans:

$$\Delta E_n = Q - W = Q_A - W_A = Q_B - W_B$$

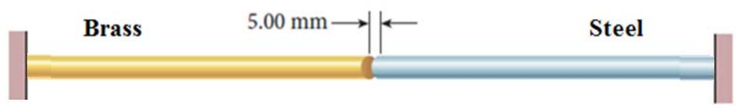
$$but\ W_A > W_B\ then\ Q_A - Q_B = W_A - W_B$$

$$Q_A > Q_B$$

Q10.

The ends of the two brass and steel rods, each 1.00 m long; as shown in the **Figure 4**, are separated by 5.00 mm at 25.0 °C. Assuming that the outside ends of both rods rest firmly against rigid supports, at what temperature will the inside ends of the rods just touch? (α_{steel}=13.0 × 10^{-6} / °C ; α_{Brass}=19.0 × 10^{-6} /C°).

Figure 4



A) 181 °C
B) 157 °C
C) 291 °C
D) 399 °C
E) 401 °C

Ans:

$$\Delta L = \Delta L_{Brass} + \Delta L_{Steel} = 5 \times 10^{-3} = L\Delta T(\alpha_{Brass} + \alpha_{Steel})$$

$$\Delta T = \frac{5 \times 10^{-3}}{L(\alpha_{Brass} + \alpha_{Steel})} = \frac{5 \times 10^{-3}}{1(19 + 13) \times 10^{-6}} = 156.3$$

$$T_f = T_i + \Delta T = 25 + 156.3 = 181.25\ ℃$$

Q11.

A 150 g of water at 30.0 °C is poured over a 60.0 g cube of ice at a temperature of – 5.00 °C. How many gram of ice has melted when the ice-water mixture has reached thermal equilibrium (specific heat of ice c_{ice} = 2220 J/kg.K; heat of fusion of ice L_F =333 kJ/kg)?

A) 54.6 g
B) 47.5 g
C) 50.0 g
D) 57.0 g
E) 59.0 g

Ans:

$$m_{ice-method} \times L_f = m_w \times c_w \times 30 - m_{ice} \times c_{ice} \times 5$$

$$= 0.15 \times 4190 \times 30 - 0.06 \times 2220 \times 5 = 18189\, J$$

$$m_{ice-method} = \frac{18189}{333 \times 10^3} = 0.05462\, kg = 54.6\, g$$

Q12.

A tea pot, with a 8.500 mm thick steel bottom plate, rests on a hot stove. The area of the bottom plate is 0.1500 m^2. The water inside the pot is at 100.0 °C, and 0.3900 kg of water is evaporated every 3.000 min. Find the temperature of the bottom plate of the pot, which is in contact with the stove. (Thermal conductivity of steel k_{steel}= 50.20 W/m.K; heat of vaporization of water L_V = 2256 kJ/kg)

A) 105.5 °C
B) 103.1 °C
C) 111.9 °C
D) 114.0 °C
E) 107.8 °C

Ans:

$$P = \frac{Q}{t} = \frac{KA(T_H - T_C)}{d} \Rightarrow Q = \frac{KA(T_H - T_C)}{d} \times t = mL_V$$

$$T_H - T_C = \frac{mL_V \times d}{KA}$$

$$T_H = T_C + \frac{mL_V d}{KAt} = 100 + \frac{0.39 \times 2256 \times 10^3 \times 8.5 \times 10^{-3}}{50.2 \times 0.15 \times 180}$$

$$T_H = 100 + 5.518 = 105.52 \text{ ℃}$$

Q13.

Which of the following ideal gases has the highest root-mean-square speed?

A) Nitrogen (M=28 g/mol) at a temperature of 30 °C
B) Argon (M=40 g/mol) at a temperature of 30 °C
C) Nitrogen (M=28 g/mol) at a temperature of 10 °C
D) Oxygen (M=32 g/mol) at a temperature of 30 °C
E) Nitrogen (M=28 g/mol) at a temperature of 15 °C

Ans:

$$A; \ V_{rms} = \sqrt{\frac{3RT}{M}}$$

Q14.

A spherical balloon of volume 4.00×10^3 cm^3 contains ideal gas helium at a pressure of 1.20×10^5 Pa. How many mol of helium are in the balloon if the average kinetic energy of the helium atoms is 3.60×10^{-22} J?

A) 3.32
B) 1.21
C) 1.55
D) 2.33
E) 4.11

Ans:

$$K_{avg} = \frac{3}{2}kT = 3.6 \times 10^{-22}; PV = NkT$$

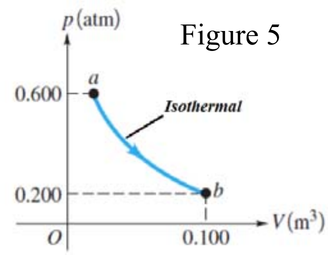
$$N = \frac{PV}{kT} = \frac{PV}{\frac{2}{3}K_{avg}} = \frac{1.2 \times 10^5 \times 4 \times 10^3 \times 10^{-6}}{\frac{2}{3} \times 3.60 \times 10^{-22}} = 2 \times 10^{24}$$

$$m = \frac{N}{N_A} = \frac{2 \times 10^{24}}{6.02 \times 10^{23}} = 3.322\, mol$$

Q15.

In the isothermal process ***a*→*b*** shown in **Figure 5**, the temperature of an ideal gas remains constant at 85.0 °C. Find the magnitude of the work done by the gas during the process $a \rightarrow b$.

Figure 5



A) 2.22×10^3 J
B) 1.90×10^3 J
C) 3.43×10^3 J
D) 4.27×10^3 J
E) 5.51×10^3 J

Ans:

$$W = nRT ln\left(\frac{V_f}{V_i}\right) = P_b V_b ln\left(\frac{P_a}{P_b}\right)$$

$$= 0.2 \times 1.01 \times 10^5 \times 0.1 \times ln\left(\frac{0.6}{0.2}\right) = 2219.2\, J$$

Q16.

A monatomic ideal gas with 0.10 mol follow the processes 1 →2 and 2 →3, as shown in **Figure 6**. Determine the net heat exchanged during these processes (1 →2 and 2 →3).

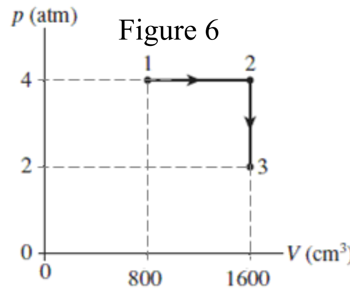


Figure 6

A) +323 J
B) −323 J
C) +271 J
D) −271 J
E) +110 J

Ans:

$$\Delta Q_P = nC_p\Delta T_{12} = \frac{C_p}{R}P\Delta V = \frac{5}{2}P\Delta V$$

$$= \frac{5}{2} \times 4 \times 1.01 \times 10^5 \times 800 \times 10^{-6} = 808\,J$$

$$\Delta Q_V = nC_V\Delta T_{23} = \frac{C_V}{R}V\Delta P = \frac{3}{2}V\Delta P$$

$$= \frac{3}{2} \times 1600 \times 10^{-6} \times (-2 \times 1.04 \times 10^5) = -484.84\,J$$

$$\Delta Q_{net} = \Delta Q_P + \Delta Q_V = 808 - 484.8 = 323.2\,J$$

Q17.

An ideal diatomic gas with 0.500 mol at T=273 K temperature and 1.00 atm pressure is compressed adiabatically to a pressure of 20.0 atm. What is the magnitude of the work done on the gas?

A) 3.84×10^3 J
B) 3.00×10^3 J
C) 2.85×10^3 J
D) 2.11×10^3 J
E) 1.84×10^3 J

Ans:

$$n = 0.5, \gamma = \frac{7}{5} = 1.4;\ C_V = \frac{5}{2}R; W = -\Delta E_{int} = -nC_V\Delta T$$

$$T_i = 273; T_f = P_fV_f \times \frac{T_i}{P_iV_i}\ ; V_i = \frac{nRT_i}{P_i} = \frac{0.5 \times 8.314 \times 273}{1.01 \times 10^5} = 0.01124\,m^3$$

$$V_f = \left(\frac{P_i}{P_f}\right)^{\frac{1}{\gamma}} \cdot V_i = \left(\frac{1}{20}\right)^{\frac{5}{7}} \times 0.01124 = 1.323 \times 10^{-3}\,m^3$$

$$T_f = P_fV_f \times \frac{T_i}{P_iV_i} = 20 \times \frac{1.323 \times 10^{-3}}{0.01124} \times 273 = 642.52\,k$$

$$W = -0.5 \times \frac{5}{2} \times 8.314 \times (6425 - 273) = -3840.25\,J$$

Q18.

Which of the following statement is **True** about change in entropy per cycle of a Carnot engine ΔS_{carnot}, a real engine ΔS_{real}, and a perfect engine $\Delta S_{Perfect}$ (impossible to build) working between the same hot reservoir (with temperature T_H) and cold reservoir (with temperature T_L)?

A) $\Delta S_{carnot} = 0$; $\Delta S_{real} > 0$; $\Delta S_{Perfect} < 0$
B) $\Delta S_{carnot} > 0$; $\Delta S_{real} = 0$; $\Delta S_{Perfect} < 0$
C) $\Delta S_{carnot} = 0$; $\Delta S_{real} > 0$; $\Delta S_{Perfect} = 0$
D) $\Delta S_{carnot} = 0$; $\Delta S_{real} = 0$; $\Delta S_{Perfect} < 0$
E) $\Delta S_{carnot} < 0$; $\Delta S_{real} = 0$; $\Delta S_{Perfect} < 0$

Ans:

A

Q19.

The efficiency of a real heat engine operating between a hot reservoir at 500 °C and a cold reservoir at 0.000 °C, is 60.0 % of the efficiency of a Carnot engine operating between the same hot and cold reservoirs. If the real heat engine and the Carnot engine do the same amount of work, what is the ratio of magnitude of $Q_{H\text{-real}} / Q_{H\text{-Carnot}}$?

A) 1.67
B) 1.44
C) 1.87
D) 1.91
E) 1.99

Ans:

$$\varepsilon_{real} = \frac{|W|}{|Q_H|real} = 0.6\frac{|W|}{|Q_H|carnot}$$

$$\frac{|Q_H|real}{|Q_H|carnot} = \frac{1}{0.6} = 1.666$$

Q20.

The coefficient of performance of a refrigerator is 5.0. The compressor uses 10 J of energy per cycle. How much heat energy is exhausted per cycle?

A) 60 J
B) 45 J
C) 55 J
D) 72 J
E) 79 J

Ans:

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

$$|Q_L| = KW = 5 \times 10 = 50\,J$$

$$|Q_H| = W + |Q_L| = 10 + 50 = 60\,J$$

$y = y_m \sin(kx - \omega t)$, $\omega = \frac{2\pi}{T}$, $k = \frac{2\pi}{\lambda}$

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

$y = 2y_m \cos(\phi/2) \sin(kx - \omega t + \phi/2)$

$y = 2y_m \sin(kx) \cos(\omega t)$

$f_n = \frac{nv}{2L}$ $n = 1, 2, 3 \ldots.$

$f_n = \frac{nv}{4L}$ $n = 1, 3, 5 \ldots.$

$v_{rms} = \sqrt{\frac{3RT}{M}}$, $K_{av} = \frac{3}{2}kT$, $PV = nRT = NkT$

$Q = nc_P \Delta T$, $Q = nc_V \Delta T$, $C_P = C_V + R$

$W = nRT \ln\left(\frac{V_f}{V_i}\right)$, $P_i V_i^{\gamma} = P_f V_f^{\gamma}$, $\gamma = \frac{C_p}{C_v}$

$\Delta S = \int_i^f \frac{dQ}{T}$, $\Delta S = nR \ln\left(\frac{V_f}{V_i}\right) + nC_V \ln\left(\frac{T_f}{T_i}\right)$

$W = |Q_H| - |Q_L|$, $\varepsilon_c = 1 - \frac{T_L}{T_H}$

$\varepsilon = \frac{W}{Q_H}$, $K = \frac{Q_L}{W}$, $K_C = \frac{T_L}{T_H - T_L}$

$s = s_m \cos(kx - \omega t)$, $\Delta p = \Delta p_m \sin(kx - \omega t)$

$\Delta p_m = \rho v \omega s_m$, $I = \frac{1}{2}\rho v \omega^2 s_m^2$,

$\beta = 10 \log\left(\frac{I}{I_o}\right)$

$v = \sqrt{\frac{B}{\rho}}$, $I = \frac{P_s}{4\pi R^2}$, $\Delta L = \frac{\lambda}{2\pi}\varphi$,

$\Delta L = m\lambda$, $\Delta L = \left(m + \frac{1}{2}\right)\lambda$ $m = 0, 1, 2 \ldots.$,

$f' = \left(\frac{v \pm v_D}{v \pm v_s}\right) f$

$T_c = T - 273$, $T_F = \frac{9}{5} T_C + 32$

$\Delta L = \alpha L \Delta T$, $\Delta V = \beta V \Delta T$, $\beta = 3\alpha$

$Q = mL$, $Q = mc\Delta T$, $W = \int P dV$

$\Delta E_{int} = Q - W$

$P_{cond} = \frac{kA(T_H - T_C)}{L}$, $P_{rad} = \sigma \varepsilon A T^4$

Constants:

$I_o = 10^{-12}$ W/m^2

1 Liter = 10^{-3} m^3

1 atm = 1.01×10^5 N/m^2

R = 8.31 J/mol K

$N_A = 6.02 \times 10^{23}$

k = 1.38×10^{-23} J/K

μ = micro = 10^{-6}, n = nano = 10^{-9}

v = 343 m/s

$\sigma = 5.67 \times 10^{-8}$ W/(m^2.K^4)

For water:

c = 4190 J/kg.K

L_F = 333 kJ/kg

L_V = 2256 kJ/kg