Q1.

A transverse sinusoidal wave is traveling on a string that is under constant tension. If you double the wavelength of the wave, what happens to the wave speed (***v***) and the frequency (***f***)?

A) ***v*** is unchanged and ***f*** is halved
B) ***v*** doubles and ***f*** is unchanged
C) ***v*** is unchanged and ***f*** doubles
D) ***v*** is halved and ***f*** is unchanged
E) both ***v*** and ***f*** are doubled

Ans:

$v = \lambda f$

$v = \text{constant}$

$f = \frac{v}{\lambda}$

$\therefore f$ is halved

Q2.

The equation for a transverse sinusoidal wave travelling on a string (μ = 0.0220 kg/m) is given by:

$y(x,t) = (0.00850)\sin(175x - 485t)$ (SI units)

The average power carried by the wave is:

A) 0.518 W
B) 0.721 W
C) 0.325 W
D) 0.421 W
E) 0.503 W

Ans:

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

$$v = \frac{\omega}{k} = \frac{485}{175} = 2.77\ m/s$$

$$\therefore P_{avg} = \frac{1}{2} \times 0.022 \times 2.77 \times [485 \times 0.0085]^2 = 0.518\ W$$

Q3.

A string fixed at both ends is oscillating in the standing wave pattern shown in **Figure 1**. The wave has a speed of 195 m/s and a frequency of 240 Hz. The amplitude of the standing wave at an antinode is 0.500 cm. Calculate the maximum transverse speed at a point that is 10.0 cm from the left end.

Figure 1

A) 5.27 m/s
B) 6.03 m/s
C) 3.02 m/s
D) 4.21 m/s
E) 7.53 m/s

Ans:

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

$$u(x,t) = -2y_m\omega \sin kx \ \sin\omega t$$

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

$$2y_m = 0.5 \text{ cm}$$

$$v = \frac{\omega}{k} \longrightarrow k = \frac{\omega}{v} = \frac{2\pi f}{v}$$

$$\Rightarrow u_{max} = 5 \times 10^{-3} \times 2\pi \times 240 \times \sin\left[\frac{2\pi \times 240}{195} \times 0.1\right] = 5.27 \text{ m/s}$$

Q4.

Two sinusoidal waves travelling on the same string are described by the equations:

$y_1(x,t) = 5.00 \sin[12.6x - 377t)$

$y_2(x,t) = 5.00 \sin[12.6x - 377t - 0.785]$,

where x, y_1 and y_2 are in cm and t is in seconds. What is the amplitude of the resultant wave?

A) 9.24 cm
B) 10.0 cm
C) 4.62 cm
D) 5.00 cm
E) 7.22 cm

Ans:

$$\text{amp} = 2y_m \cdot \cos\frac{\phi}{2}$$

$$= 2 \times 5.00 \times \cos\left(\frac{0.785}{2}\right) = 9.24 \text{ cm}$$

Q5.

A point source emits constant sound power. If you double the distance from the source, how much is the decrease in the sound level?

A) 6.0 dB
B) 12 dB
C) 3.0 dB
D) 4.8 dB
E) 5.5 dB

Ans:

$$I = \frac{P}{4\pi r^2}$$

$$\beta = 10\log\left(\frac{I}{I_o}\right) = 10\log\left(\frac{P}{4\pi I_o r^2}\right)$$

$$\beta_1 = 10\log\left(\frac{P}{4\pi I_o r_1^2}\right)$$

$$\beta_2 = 10\log\left(\frac{P}{4\pi I_o r_2^2}\right)$$

$$\beta_2 - \beta_1 = 10\log\left(\frac{P}{4\pi I_o r_2^2}\cdot\frac{4\pi I_o r_1^2}{P}\right)$$

$$= 10\log\left(\frac{r_1^2}{r_2^2}\right) = 20\log\left(\frac{r_1}{r_2}\right) = 20\log\left(\frac{1}{2}\right) = -6.0\ \text{dB}$$

Q6.

A sound source and a detector are moving with the same speed along a straight line. In which situation will there be a maximum frequency shift due to the Doppler effect? (recede = move away)

A) Source and detector are moving toward each other.
B) Source and detector are moving away from each other.
C) Detector moves toward a receding source.
D) Source moves toward a receding detector.
E) The shift is always equal to zero.

Ans:

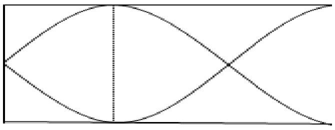
$$f' = f\left(\frac{v \pm v_D}{v \mp v_S}\right)$$

$$f'_{max} = f\left(\frac{v + v_D}{v - v_S}\right)$$

Q7.

A pipe, that is closed at one end, has a length of 1.2 m. The third harmonic standing wave is set up in the pipe. At what distance from the closed end is the first displacement antinode? The speed of sound in air is 343 m/s.

A) 0.40 m
B) 1.2 m
C) 0.60 m
D) 0.24 m
E) 0.48 m



Ans:

$$f_n = \frac{nv}{4L}$$

$$f_3 = \frac{3v}{4L} = \frac{3 \times 343}{4 \times 1.2} = 214 \text{ Hz}$$

$$\lambda = \frac{v}{f} = \frac{343}{214} = 1.6 \text{ m}$$

$$d = \frac{\lambda}{4} = \frac{1.6}{4} = 0.4 \text{ m}$$

Q8.

Two sound sources are driven by the same generator and face each other. The sources are separated by 12.0 m and emit sound of frequency 686 Hz. You stand at a point of constructive interference between the two sources along the line connecting them. How far must you walk to move to a point of destructive interference? The speed of sound in air is 343 m/s.

A) 0.125 m
B) 0.250 m
C) 0.375 m
D) 0.345 m
E) 0.274 m

Ans:

The distance from a node and an antinode is $\frac{\lambda}{4}$

$$\lambda = \frac{v}{f} = \frac{343}{688} = 0.5 \text{ m}$$

$$\Rightarrow d = \frac{0.5}{4} = 0.125 \text{ m}$$

Q9.

A 2.00-kg copper container is at a temperature of 195 °C. You pour 0.100 kg of water initially at 25.0 °C into the container and close the container so that no steam escapes. How much water boils off? Assume no heat is lost to the surroundings. The specific heat of copper is 386 J/kg.K.

A) 18.6 g
B) 23.3 g
C) 32.5 g
D) zero
E) 100 g

Ans:

$T_f = 100\ ^\circ C$

$Q_{1w} = m_w c_w \Delta T = 0.1 \times 4190 \times 75 = 31425\ \text{J}$

$Q_{2c} = m_c c_c \Delta T = 2 \times 386 \times 95 = 73340\ \text{J}$

$\Delta = Q_{2c} - Q_{1w} = 41915\ \text{J}\ \longleftarrow$ heat to boil water

$$\Delta = m_w \cdot L_v \Rightarrow m_w = \frac{\Delta}{L_v} = \frac{41915}{2256 \times 103} = 18.6\ \text{g}$$

Q10.

An aluminum hemispherical shell (half sphere that is empty inside) has a diameter of 55 m at – 15 °C. What is the increase in the volume of the hemisphere when the temperature rises to 35 °C? The coefficient of linear expansion of aluminum is 2.3 × 10^{-5} $(^\circ C)^{-1}$.

A) 150 m^3
B) 50 m^3
C) 120 m^3
D) 80 m^3
E) 35 m^3

Ans:

$\Delta V = 3\alpha\, V_0\, \Delta T$

$$V_0 = \frac{1}{2} \times \frac{4\pi}{3} R_0^3 = \frac{2\pi}{3} R_0^3$$

$$\Rightarrow \Delta V = 3\alpha \cdot \frac{2\pi}{3} R_0^3 \cdot \Delta T$$

$$= 2\pi\, \alpha\, R_0^3\, \Delta T$$

$$= (2\pi)(2.3 \times 10^{-5})(27.5)^3 \times 50 = 150\ m^3$$

Q11.

A metallic rod is 50 cm long and has a cross sectional area of 1.3 cm^2. The left end of the rod is in contact with a reservoir at 100 ^oC, and the right end is in contact with a reservoir at 0 ^oC. In steady state, what is the temperature at a point that is 15 cm from the left end?

A) 70 ^oC
B) 30 ^oC
C) 43 ^oC
D) 57 ^oC
E) 50 ^oC

Ans:

$$P_{cond} = \frac{k\,A\,\Delta T}{L} = 100\,\frac{k\,A}{L}$$

$$P_x = \frac{kA(100 - T)}{15} = \frac{100\,kA}{50}$$

$$\Rightarrow 100 - T = 30 \;\Rightarrow T = 70\,^\circ C$$

Q12.

The pressure and volume of 0.400 moles of an ideal diatomic gas are 400 kPa and 2.00 L. The gas is compressed adiabatically to one-half of its original volume. What is the change in the internal energy of the gas?

A) 639 J
B) 383 J
C) 263 J
D) 201 J
E) 713 J

Ans:

$$T_i = \frac{P_i V_i}{nR} = \frac{4\times 10^5 \times 2\times 10^{-3}}{0.4\times 8.31} = 240.67\ K$$

$$T_i V_i^{\gamma-1} = T_f V_f^{\gamma-1} \Rightarrow T_f = \left(\frac{V_i}{V_f}\right)^{\gamma-1}\cdot T_i = 2^{0.4}\times T_i = 317.57\ K$$

$$\Delta E_{int} = n\,C_v\,\Delta T$$

$$= 0.4\times 2.5\times 8.31\times(317.57 - 240.67) = 639\ J$$

Q13.

An ideal gas with $C_P = 7R/2$ is compressed at constant pressure to one-fourth of its original volume. If the work done on the gas has magnitude 500 J, what is the change in the internal energy of the gas?

A) – 1250 J
B) + 1250 J
C) + 2500 J
D) + 1750 J
E) – 1750 J

Ans:

$$W = p\,\Delta V = n\,R\,\Delta T$$

$$\Delta E_{int} = n\,C_v\,\Delta T = (n)\left(\frac{5R}{2}\right)\Delta T = \frac{5}{2}n\,R\,\Delta T$$

$$= \frac{5}{2} \times (-500) = -1250\ \text{J}$$

Q14.

If an ideal gas is compressed isothermally:

A) Heat is transferred from the gas.
B) Heat is transferred to the gas.
C) No work is done in the process.
D) Work is done by the gas.
E) The internal energy of the gas decreases.

Ans:

$$T = \text{constant}$$

$$\Delta T = 0 \ \Rightarrow\ \Delta E_{int} = 0$$

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

$$Q \text{ is } (-) \ \text{ if } \ W \text{ is } (-)$$

Q15.

The temperature of an ideal gas increases from 200 °C to 600 °C. The ratio of the final RMS speed to the initial RMS speed is:

A) 1.36
B) 1.73
C) 0.577
D) 0.736
E) 1.10

Ans:

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

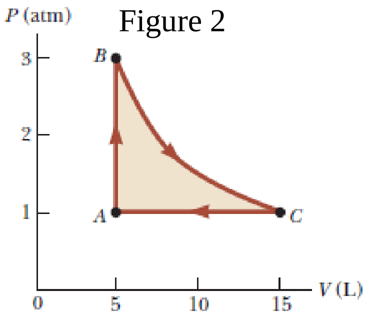
$$\frac{V_f}{V_i} = \sqrt{\frac{3RT_f}{M} \cdot \frac{M}{3RT_i}} = \sqrt{\frac{T_f}{T_i}} = \sqrt{\frac{600 + 273.15}{200 + 273.15}} = 1.36$$

Q16.

A sample of an ideal monatomic gas is taken through the cyclic process shown in **Figure 2**, where process BC is isothermal. How much heat is exchanged in one cycle?

A) 654 J into the gas
B) 654 J out of the gas
C) 267 J out of the gas
D) 267 J into the gas
E) 166 J out of the gas

Figure 2



Ans:

In 1 cycle: $Q_{tot} = W_{tot}$

$$\therefore Q_{tot} = \overset{0}{W_{AB}} + W_{BC} + W_{CA}$$

$$W_{BC} = p_B V_B \cdot \ln 3 = 15 \times 1.01 \times 10^2 \times \ln 3 = 1664.4 \text{ J}$$

$$W_{CA} = 1.01 \times 10^2 \times (-10) = -1010 \text{ J}$$

$$\Rightarrow Q_{tot} = +654 \text{ J}$$

Q17.

A Carnot engine absorbs 450 kJ from a hot reservoir and performs 250 kJ of work in each cycle. If the temperature of the cold reservoir is 20.0 °C, what is the temperature of the hot reservoir?

A) 386 °C
B) 45.0 °C
C) 255 °C
D) 36.0 °C
E) 659 °C

Ans:

$$Q_H = 450\ kJ$$

$$Q_L = Q_H - W = 450 - 250 = 200\ kJ$$

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

$$T_H = \frac{Q_H}{Q_L} \cdot T_L = \frac{450}{200} \times (20 + 273) = 659.59\ K = 386\ ^\circ C$$

Q18.

One kilogram of water at 20 °C is placed in an ideal refrigerator and cools to 5.0 °C in 1.0 h. If the power of the refrigerator is 8.0 W, what is its coefficient of performance?

A) 2.2
B) 2.9
C) 3.6
D) 1.9
E) 4.2

Ans:

$$Q_L = m\,c\,\Delta T = 1 \times 4190 \times 15 = 62850\ J$$

$$W = P \cdot t = 8 \times 3600 = 28800\ J$$

$$K = \frac{Q_L}{W} = \frac{62850}{28800} = 2.2$$

Q19.

An amount of water (150 g) initially at 80.0 °C cools to room temperature 25.0 °C. What is the change in entropy of the room? Neglect the change in the temperature of the room.

A) 116 J/K
B) 151 J/K
C) 629 J/K
D) 125 J/K
E) 377 J/K

Ans:

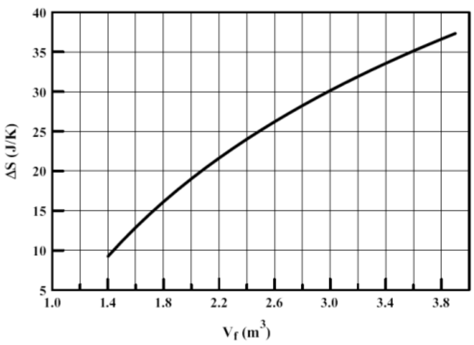
$$Q = m\, c\, \Delta T = 0.15 \times 4190 \times 55 = 34567.5$$

$$\Delta S_{room} = \frac{Q}{T} = \frac{34567.5}{25 + 273.5} = 116 \text{ J/K}$$

Q20.

An ideal gas sample undergoes a reversible isothermal expansion. **Figure 3** gives the change ***ΔS*** in entropy of the gas versus final volume V_f of the gas. How many moles are in the sample?

Figure 3



A) 3.3
B) 4.2
C) 2.1
D) 6.1
E) 3.9

Ans:

$$\Delta S = \int \frac{dQ}{T} = \frac{nRT}{T} \ln \frac{V_f}{V_i} = n\,R \ln \frac{V_f}{V_i}$$

$$\Delta S = n\,R \ln V_f - n\,R \ln V_i$$

$$\left.\begin{array}{l} \Delta S_{3.6} = n\,R \ln 3.6 - x \\ \Delta S_{3.0} = n\,R \ln 3.0 - x \end{array}\right\} 35 - 30 = n\,R \ln 1.2 \Rightarrow n = \frac{5}{R \ln 1.2} = 3.3$$
