Q1.

Fully destructive interference between two identical sinusoidal waves occurs only if they:

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

Q2.

A 4.00-m long string, clamped at both ends, vibrates at 200 Hz. If the string resonates in six loops, what is the speed of transverse waves on the string?

A) 267 m/s
B) 133 m/s
C) 100 m/s
D) 328 m/s
E) 400 m/s

Ans:

$$1 \text{ loop} = \frac{\lambda}{2}$$

$$\therefore 6 \text{ loops} = 3\lambda = L$$

$$\Rightarrow \lambda = \frac{L}{3} = \frac{4}{3}\text{m}$$

$$\therefore V = f\lambda = 200 \times \frac{4}{3} = 267 \text{ m/s}$$

Q3.

A string of linear mass density 64 g/m is stretched under tension of magnitude 40 N. A wave is traveling along the string with a frequency of 120 Hz and amplitude of 8.0×10^{-3} m. What is the average rate of energy that must be supplied by a generator to produce this wave in the string?

A) 29 W
B) 3.6 W
C) 0.73 W
D) 0.24 W
E) 15 W

Ans:

$$P = \frac{1}{2}\mu\omega^2 y_m^2 v\ ;\ \ v = \sqrt{\frac{\tau}{\mu}}$$

$\mu = 64 \times 10^{-3}$ kg/m, $\tau = 40$ N , $y_m = 8 \times 10^{-3}$ m

$f = 120\ \text{Hz} \Rightarrow \ \omega = 2\pi f = 240\ \pi\ \text{rad/s}$

$\Rightarrow P = 29\ \text{W}$

Q4.

Which of the following answers is the correct equation of a wave traveling along negative x-axis with a speed of 220 m/s, frequency 70 Hz and amplitude 0.025 m? (x is in meters and t is in seconds).

A) y = 0.025 sin(2.0 x + 440 t)
B) y = 0.025 sin(2.0 x – 440 t)
C) y = 0.025 sin(3.1 x + 70 t)
D) y = 0.025 sin(3.1 x – 70 t)
E) y = 0.025 sin(2.5 x + 220 t)

Ans:

$\omega = 2\pi f = 2\pi \times 70 = 440$

$$k = \frac{2\pi,}{\lambda}\ (v = f\lambda) = \frac{2\pi f}{v} = \frac{440}{220} = 2$$

Q5.

Sound waves travel at 343 m/s in air and at 1500 m/s in water. A 256-Hz sound wave is generated inside a pool of water, and you hear the sound standing beside the pool. In the air,

A) the frequency of the sound is the same, but its wavelength is shorter.
B) the frequency of the sound is higher, but its wavelength stays the same.
C) the frequency of the sound is lower, and its wavelength is longer.
D) the frequency of the sound is lower, and its wavelength is shorter.
E) both the frequency and the wavelength of the sound stay the same.

Ans:

$\lambda = \frac{v}{f}$, f is constant

Q6.

A car moving at 40.0 m/s approaches a stationary whistle that emits a 200 Hz sound. The speed of sound in air is 343 m/s. What is the frequency of the sound heard by the driver of the car?

A) 223 Hz
B) 200 Hz
C) 177 Hz
D) 179 Hz
E) 226 Hz

Ans:

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

$v_s = 0, v_D = 40, v = 343, f = 200$

$\Rightarrow f' = 223\ \text{Hz}$

Q7.

Consider an organ pipe A with both ends open and an organ pipe B with one end open. The third harmonic of B has the same frequency as the second harmonic of A. What is the ratio of their lengths, L_A/L_B?

A) 1.3
B) 0.75
C) 1.0
D) 2.0
E) 0.50

Ans:

For pipe A: $f_n = \frac{nv}{2L}$

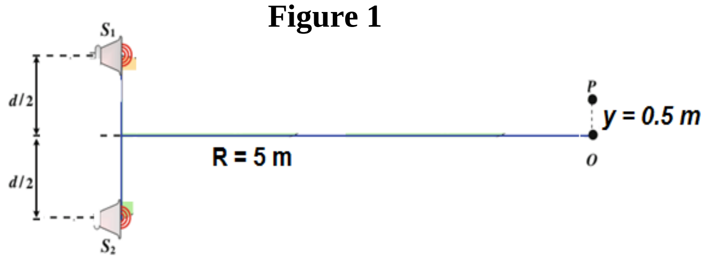
For pipe B: $f_n = \frac{nv}{4L}$

Given that $2 \cdot \frac{v}{2L_A} = 3 \cdot \frac{v}{4L_B} \Rightarrow \frac{L_A}{L_B} = \frac{4}{3} = 1.3$

Q8.

Two identical speakers, S_1 and S_2, are placed 2 m apart, as shown in **Figure 1,** and emit sound waves driven by the same oscillator. A listener is originally located at point O, which is a distance R = 5 m from the center of the line connecting the two speakers. The listener walks to point P, which is a distance y = 0.5 m above O, and hears the first minimum in sound intensity. Find the wavelength of the sound wave.

Figure 1



A) 0.4 m
B) 0.2 m
C) 0.5 m
D) 1 m
E) 5 m

Ans:

First minimum $\Rightarrow S_2P - S_2P = \frac{\lambda}{2}$

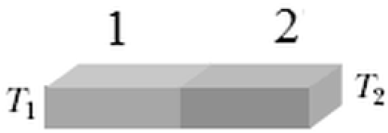
$$S_2P = \sqrt{R^2 + \left(\frac{d}{2} + y\right)^2} = 5.22, \qquad S_1P = \sqrt{R^2 + \left(\frac{d}{2} - y\right)^2} = 5.02$$

$$\Rightarrow \lambda = 2\,(5.22 - 5.02) = 0.4 \text{ m}$$

Q9.

Two metal rods of identical dimensions (length 20.0 cm and cross-sectional area 14.0 cm^2 each) are welded end to end, as shown in **Figure 2**. T_1= 0 ^{0}C and T_2 = 100 ^{0}C. The thermal conductivities of the rods are k_1 = 109 W/m.K and k_2 = 401 W/m.K. Find the conduction rate through the rods when steady state is reached:

Figure 2



A) 60.0 W
B) 25.5 W
C) 120 W
D) 30.0 W
E) 42.9 W

Ans:

At steady state $k_1 \frac{A}{L}(T - T_1) = \frac{Q}{t} = k_2 \frac{A}{L}(T_2 - T)$

(where T is the temperature at the interface)

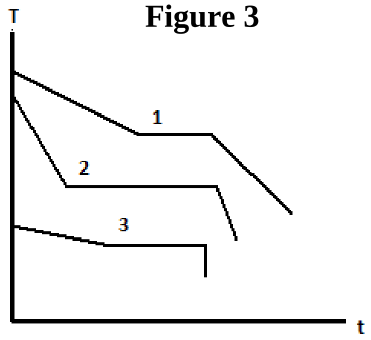
$\Rightarrow T = 351.6 \text{ K}$

$$\therefore \frac{Q}{t} = k_1 \frac{A}{L}(T - T_1) = 60 \text{ W}$$

Q10.

Three different materials of identical mass are placed one at a time in a special freezer that can extract energy from the material at a certain constant rate. During the cooling process, each material begins in the liquid state and ends in the solid state; **Figure 3** shows the temperature *T* versus time *t*. Rank the materials according to their specific heat in the liquid state, greatest first.

Figure 3



A) 3, 1, 2
B) 3, 2, 1
C) 1, 2, 3
D) 1, 3, 2
E) 2, 3, 1

Ans:

$$\frac{Q}{t} = \frac{mc\Delta T}{t} = \text{constant}$$

$$\Rightarrow c \cdot \frac{\Delta T}{t} = \text{constant}$$

$$\frac{\Delta T}{t} = \text{slope of T vs t graph}$$

High temperature portion of the graph represents liquid state.

Slope of 2 > slope of 1> slope of 3

$$\Rightarrow c_2 < c_1 < c_3$$

Q11.

What is the minimum amount of energy required to completely melt 150 g of silver initially at 298 K? (For Silver: Specific heat = 236 J/kg.K, Melting point = 1235 K, Heat of fusion = 105 kJ/kg)

A) 48.9 kJ
B) 58.6 kJ
C) 33.2 kJ
D) 15.8 kJ
E) 42.8 kJ

Ans:

$$Q = mc\Delta T + mL_F = 48.9 \text{ kJ}$$

Q12.

A thermodynamic system undergoes a process in which its internal energy decreases by 600 J. At the same time, 250 J of work is done on the system. The heat energy to the system is

A) –850 J
B) +350 J
C) +850 J
D) –350 J
E) 0 J

Ans:

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

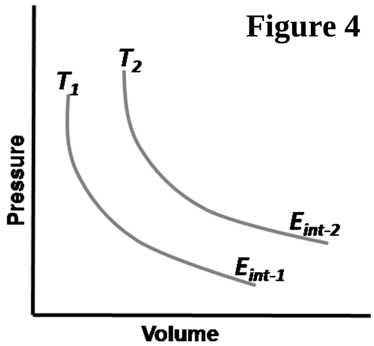
$$= (-250) + (-600)$$

$$= -850\ \mathrm{J}$$

Q13.

Variation of Pressure with Volume of an ideal gas at constant temperatures T_1 and T_2 is represented by two isotherms shown in **Figure 4**. Internal energy of the gas is denoted by E_{int}. Which of the following is true?

Figure 4



A) $E_{int\text{-}1} < E_{int\text{-}2}$
B) $T_1 > T_2$
C) $T_1 = T_2$
D) $E_{int\text{-}1} > E_{int\text{-}2}$
E) $E_{int\text{-}1} = E_{int\text{-}2}$

Ans:

$$E_{int} \propto T$$

From the graph $T_1 < T_2$

$$\therefore E_{int-1} < E_{int-2}$$

Q14.

An ideal gas is enclosed in a cylinder. If the temperature of the gas is increased from 100 ^oC to 200 ^oC at constant volume, the pressure of the gas will change from P to

A) 1.27 P
B) 2.00 P
C) 3.00 P
D) 0.500 P
E) 1.50 P

Ans:

Constant V

$$\therefore \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$T_1 = 273 + 100 = 373\ K$$

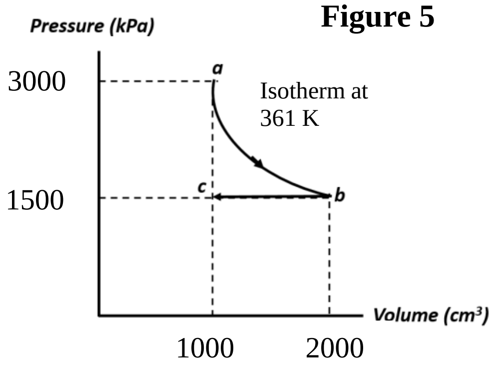
$$T_2 = 273 + 200 = 473\ K$$

$$\Rightarrow \frac{P_2}{P_1} = \frac{T_2}{T_1} = 1.27$$

Q15.

One mole of ideal gas goes from initial state 'a' to final state 'c' as shown in **Figure 5**, where *ab* is isotherm at 361.0 K and *bc* is isobaric at 1500 kPa. Find the total work done by the gas along the path *abc*.

Figure 5



A) 579.4 J
B) 2079 J
C) 3579 J
D) 1500 J
E) 9000 J

Ans:

$$W_{abc} = W_{ab} + W_{bc}$$

$$= nRT\,ln\left(\frac{v_f}{v_i}\right) + P \cdot \Delta v$$

$$= 1 \times 8.31 \times 361 \ln(2) + 1500 \times 10^3 \times (1000 - 2000) \times 10^{-6} = 579.4\ J$$

Q16.

When 20.9 J was added as heat to an ideal gas, its volume changed from 50.0 cm^3 to 100 cm^3 while its pressure remained at 1.00 atm. The C_p of the gas is

A) 34.4 J/mol.K
B) 17.2 J/mol.K
C) 20.9 J/mol.K
D) 50.0 J/mol.K
E) 25.0 J/mol.K

Ans:

$$Q = nc_p \Delta T = \cancel{n} c_p \cdot \frac{P\Delta V}{\cancel{n}R}$$

$$\Rightarrow c_p = \frac{QR}{P\Delta V} = 34.4 \text{ J mol. K}$$

Q17.

You wish to increase the coefficient of performance of an ideal refrigerator that works between temperatures T_L and T_H. Which of the following (assume that the slight increase or decrease in T_L or T_H is the same in all answers) would give the greatest increase?

A) Running the cold reservoir at slightly higher temperature.
B) Running the cold reservoir at slightly lower temperature.
C) Moving the refrigerator to a slightly warmer room.
D) Moving the refrigerator to a slightly cooler room.
E) Restarting the refrigerator.

Ans:

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

$$= \frac{T_L}{T_H - T_L}$$

Q18.

The efficiency of a car engine is 20 % when the engine does 6.0 kJ of work per cycle. Assume the process is reversible. After a tune-up, the efficiency increased to 30 %. By how much the energy lost is reduced for the same amount of work?

A) 10 kJ
B) 12 kJ
C) 20 kJ
D) 16 kJ
E) 18 kJ

Ans:

$$\varepsilon = \frac{W}{Q_H} = \frac{W}{Q_L + W} \Rightarrow Q_L = W\left(\frac{1}{\varepsilon} - 1\right)$$

$$\Rightarrow Q_{L1} = 6\left(\frac{1}{0.2} - 1\right) = 24 \text{ kJ}$$

$$Q_{L2} = 6\left(\frac{1}{0.3} - 1\right) = 14 \text{ kJ}$$

$$\therefore Q_{L1} - Q_{L2} = 10 \text{ kJ}$$

Q19.

A 20-g ice cube at –10 ^{0}C is dropped in a lake whose temperature is 15 ^{0}C. Calculate the change in entropy of the lake as the ice cube comes to thermal equilibrium with the lake. Specific heat of ice = 2220 J/kg.K, and the effect of ice cube on the lake's temperature is negligible.

A) –29 J/K
B) +29 J/K
C) +31 J/K
D) –31 J/K
E) 0

Ans:

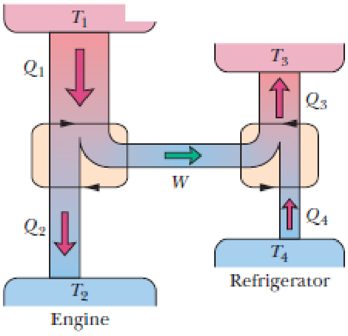
$$\Delta S = \frac{\Delta Q}{T} = -\left[mc_{ice}\left(0 - (-10)\right) + mL_f + mc_{water}(15 - 0)\right] / (273 + 15)$$

$$= -29 \text{ J/K}$$

Q20.

Figure 6 represents a Carnot engine that works between temperatures T_1 = 500 K and T_2 = 250 K, and drives a Carnot refrigerator that works between temperatures T_3 = 350 K and T_4 = 250 K. What is the ratio Q_3/Q_1?

Figure 6



A) 1.75
B) 1.25
C) 1.67
D) 1.43
E) 3.50

Ans:

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2} = 2 \Rightarrow Q_2 = \frac{1}{2}Q_1$$

$$\frac{Q_3}{Q_4} = \frac{T_3}{T_4} = \frac{7}{5} \Rightarrow Q_4 = \frac{5}{7}Q_3$$

$$Q_1 - Q_2 = W = Q_3 - Q_4$$

$$\Rightarrow \frac{1}{2}Q_1 = \frac{2}{7}Q_3 \Rightarrow \frac{Q_3}{Q_1} = \frac{7}{4} = 1.75$$