Q1.

A string has a mass of 0.20 g and a length of 1.6 m. A sinusoidal wave is travelling on this string, and is given by: *y (x,t) = 0.030 sin (0.30 x – 80 t + 3π/2)* (SI units). What is the magnitude of the tension in the string?

A) 8.9 N
B) 3.3 N
C) 4.7 N
D) 9.2 N
E) 5.4 N

Ans:

$$\mu = \frac{m}{L} = \frac{2.0 \times 10^{-4}}{1.6} = 1.25 \times 10^{-4}\ \mathrm{kg/m}$$

$$v = \frac{\omega}{k} = \frac{80}{0.30} = 266.7\ \mathrm{m/s}$$

$$v = \sqrt{\frac{\tau}{\mu}} \rightarrow \tau = \mu . v^2 = 8.9\ \mathrm{N}$$

Q2.

The average power transmitted by a sinusoidal wave on a stretched string does not depend on

A) the length of the string.
B) the frequency of the wave.
C) the wavelength of the wave.
D) the tension in the string.
E) the amplitude of the wave.

Ans:

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

Q3.

A standing wave is established on a 3.0 m long string fixed at both ends. The string vibrates in three loops with an amplitude of 1.0 cm. If the wave speed is 100 m/s, what is the frequency?

A) 50 Hz
B) 100 Hz
C) 33 Hz
D) 25 Hz
E) 10 Hz

Ans:

$$\lambda_n = \frac{2L}{n} \Rightarrow \lambda_3 = \frac{2L}{3} = \frac{2 \times 3.0}{3} = 2.0\ \mathrm{m}$$

$$v = \lambda f \Rightarrow f = \frac{v}{\lambda} = \frac{100}{2.0} = 50\ \mathrm{Hz}$$

Q4.

A string of length 2.5 m is fixed at both ends. A standing wave of frequency 100 Hz is set up on the string. The distance between two adjacent nodes is 0.50 m. What is the fundamental frequency of the string?

A) 20 Hz
B) 100 Hz
C) 40 Hz
D) 500 Hz
E) 60 Hz

Ans:

$$\frac{\lambda}{2} = 0.50 \text{ m} \Rightarrow \lambda = 1.0 \text{ m}$$

$$\lambda_n = \frac{2L}{n} \Rightarrow n = \frac{2L}{\lambda} = \frac{2 \times 2.5}{1.0} = 5$$

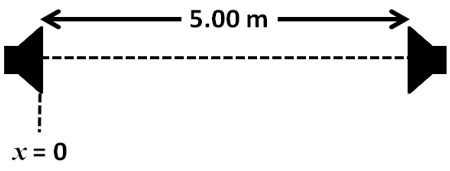
$$f_n = n.f_1 \Rightarrow f_1 = \frac{f}{n} = \frac{100}{5} = 20 \text{ Hz}$$

Q5.

Two speakers, facing each other and separated by a distance of 5.00 m, are driven by the same oscillator, as shown in **Figure 1**. A listener starts walking from the left speaker toward the right one, along the line joining them. He hears the fist minimum at x = 1.00 m. Find the frequency of the oscillator. Speed of sound = 343 m/s.

A) 57.2 Hz
B) 114 Hz
C) 42.9 Hz
D) 85.8 Hz
E) 34.3 Hz

Fig # 1



Ans:

$$\Delta L = L_2 - L_1 = 4 - 1 = 3 \text{ m}$$

$$\text{But: } \Delta L = \frac{\lambda}{2} \leftarrow \text{First minimum}$$

$$\Rightarrow \lambda = 2.\Delta L = 6.0 \text{ m}$$

$$v = \lambda f$$

$$\Rightarrow f = \frac{v}{\lambda} = \frac{343}{6.0} = 57.2 \text{ Hz}$$

Q6.

A point source uniformly emits 440 W of sound in all directions. How far from the source will the sound level be 106 dB?

A) 29.7 m
B) 21.8 m
C) 32.5 m
D) 38.1 m
E) 52.5 m

Ans:

$$\beta = 10.\log\left(\frac{I}{I_0}\right) \Rightarrow I = I_0.(10)^{\beta/10} = 10^{-12} \times (10)^{10.6}$$
$$= 10^{-1.4} = 0.0398\ W/m^2$$

$$I = \frac{P_s}{4\pi r^2} \Rightarrow r = \sqrt{\frac{P_s}{4\pi I}} = \sqrt{-\frac{440}{4\pi \times 0.0398}} = 29.7\ m$$

Q7.

A train approaches a mountain at a speed of 20.8 m/s. The train's engineer sounds a whistle that emits sound with a frequency of 420 Hz. What will be the frequency of the sound reflected from the mountain, as heard by the engineer? Speed of sound = 343 m/s.

A) 474 Hz
B) 430 Hz
C) 446 Hz
D) 420 Hz
E) 400 Hz

Ans:

$$\text{Train} \rightarrow \text{Mountain: } f' = f_0 \frac{v}{v-w}$$
$$\text{Mountain} \rightarrow \text{Train: } f'' = f' \frac{v+w}{v}$$

w = speed of train

$$\Rightarrow f'' = f_0.\frac{v+w}{v-w} = 420 \times \frac{343+20.8}{343-20.8} = 474\ Hz$$

Q8.

Tube A has length L_A and is open at both ends. Tube B has length L_B and is closed at one end. If the fundamental frequencies of the two tubes match then:

A) $L_B = L_A/2$
B) $L_B = L_A$
C) $L_B = L_A/4$
D) $L_B = 2\,L_A$
E) $L_B = 4\,L_A$

Ans:

$$f_{nA} = \frac{nv}{2L_A} \Rightarrow f_{1A} = \frac{v}{2L_A}$$

$$f_{nB} = \frac{nv}{4L_B} \Rightarrow f_{1B} = \frac{v}{4L_B}$$

$$f_{1A} = f_{1B}: \quad \frac{v}{2L_A} = \frac{v}{4L_B}$$

$$\Rightarrow L_B = L_A/2$$

Q9.

A bridge is made of segments of concrete, each of length L = 50 m, that are placed end to end. Every two adjacent segments are separated by a spacing ΔL to allow for thermal expansion, without the two segments touching. If the temperature changes by 150 F°, what should be the minimum value of ΔL? The coefficient of linear expansion of concrete is 12×10^{-6} $(^{\circ}C)^{-1}$.

A) 5.0 cm
B) 7.5 cm
C) 10 cm
D) 2.5 cm
E) 9.5 cm

Ans:

$$T_F = \frac{9}{5} T_C + 32 \Rightarrow \Delta T_F = \frac{9}{5} \Delta T_C \Rightarrow \Delta T_C = \frac{5}{9} \Delta T_F$$

$$\Delta L = \alpha . L_0 . \Delta T = 12 \times 10^{-6} \times 50 \times \frac{5}{9} \times 150$$

$$= 0.05 \text{ m} = 5.0 \text{ cm}$$

Q10.

A 4.0 kg block of ice at 0.0 °C is mixed with 4.0 kg of steam at 100 °C. What is the final equilibrium temperature of the system?

A) 100 °C
B) 0.0 °C
C) 50 °C
D) 85 °C
E) 22 °C

Ans:

$$Q_{i1} = m_i . L_F = 4 \times 333 = 1332 \text{ kJ}$$

$$Q_{i2} = m_i . C_w . \Delta T = 4 \times 4190 \times 100 = 1676 \text{ kJ}$$

$\therefore$ Ice needs $Q_{i1} + Q_{i2} = 3008$ kJ to melt and reach 100°C

$$Q_s = m_s . L_v = 4 \times 2256 = 9024 \text{ kJ}$$

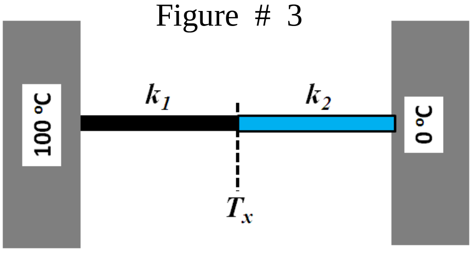
$\therefore$ Steam has enough heat to melt an heat ice $\therefore$ $T_f = 100°C$

Q11.

Two rods, made of different materials but having the same length and diameter, are welded end to end between two thermal reservoirs, as shown in **Figure 3**. In steady state, what is the temperature (T_x) at the junction between the two rods?

A) 100 $k_1/(k_1 + k_2)$
B) 100 $k_2/(k_1 + k_2)$
C) 100 $k_1 k_2/(k_1 + k_2)$
D) 50 $k_1/(k_1 + k_2)$
E) 50 $k_2/(k_1 + k_2)$

Figure # 3



Ans:

$$P_1 = \frac{k_1 . A . (100 - T_x)}{L}$$

$$P_2 = \frac{k_2 . A . (T_x - 0)}{L}$$

Steady state: $P_1 = P_2$

$$\Rightarrow k_1 (100 - T_x) = k_2 T_x$$

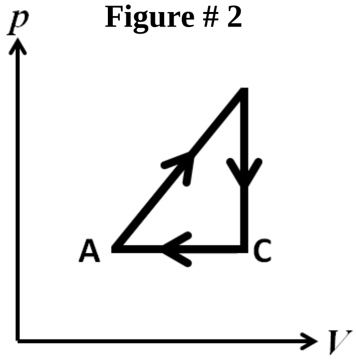
$$100k_1 - k_1 T_x = k_2 T_x \Rightarrow T_x = 100 . \frac{k_1}{k_1 + k_2}$$

Q12.

An ideal gas undergoes the cyclic process shown in **Figure 2**. What are the signs of the heats Q_{AB}, Q_{BC}, Q_{CA}, respectively?

A) positive, negative, negative
B) positive, negative, positive
C) positive, positive, negative
D) negative, positive, positive
E) negative, positive, negative

Figure # 2



Ans:

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

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

	ΔE	W	Q
AB	+	+	+
BC	–	0	–
CA	–	–	–

Q13.

Two moles of a monatomic ideal gas are initially at 27.0 °C and occupy a volume of 20.0 L. The gas is expanded at constant pressure until the volume is doubled. Find the change in the internal energy of the gas.

A) 7.48 kJ
B) 12.5 kJ
C) 0.673 kJ
D) 1.12 kJ
E) 5.44 kJ

Ans:

$$\Delta E_{int} = n.c_v.\Delta T = n.\left(\frac{3}{2}R\right)\Delta T = \frac{3}{2}nR\Delta T$$

$$pV = nRT \Rightarrow nR\Delta T = P.\Delta V = P_i.(2V_i - V_i) = P_i V_i = nRT_i$$

$$\Rightarrow \Delta E_{int} = \frac{3}{2}nRT_i = \frac{3}{2} \times 2 \times 8.31 \times (27 + 273) = 7479\text{ J} = 7.48\text{ kJ}$$

Q14.

An ideal diatomic gas, initially at 20.0 °C, is compressed adiabatically from 1.00 L to 0.500 L. What is the final temperature of the gas?

A) 387 K
B) 299 K
C) 465 K
D) 305 K
E) 117 K

Ans:

$$\text{Diatomic: } \gamma = \frac{C_p}{C_v} = \frac{7R/2}{5\,R/2} = \frac{7}{5} = 1.4$$

$$\text{Adiabatic: } T_i . V_i^{\gamma-1} = T_f . V_f^{\gamma-1}$$

$$\Rightarrow T_f = \left(\frac{V_i}{V_f}\right)^{\gamma-1} . T_i = \left(\frac{1.00}{0.500}\right)^{0.4} \times 293.15 = 387\text{ K}$$

Q15.

The speeds of four particles are as follows: v_1 = 1.0 m/s, v_2 = 2.0 m/s, v_3 = 3.0 m/s and v_4 = 4.0 m/s. What is their root mean square speed?

A) 2.7 m/s
B) 2.5 m/s
C) 1.9 m/s
D) 5.5 m/s
E) 3.2 m/s

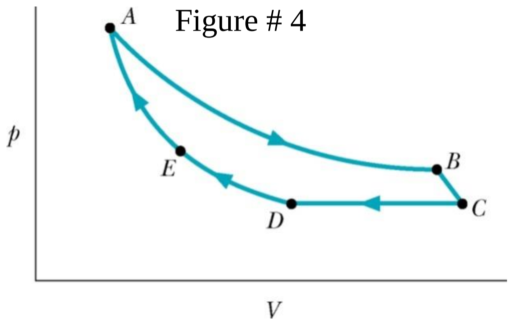
Ans:

$$(v^2)_{avg} = \frac{1.0 + 4.0 + 9.0 + 16}{4} = 7.5\ (m/s)^2$$

$$v_{rms} = \sqrt{(v^2)_{avg}} = \sqrt{7.5} = 2.7\ m/s$$

Q16.

Figure 4 shows a cycle consisting of five paths: *AB* is isothermal at 300 K, *BC* is adiabatic with work = 8.0 J, *CD* is isobaric at 5.0 atm, *DE* is isothermal, and *EA* is adiabatic with a change of internal energy of 10 J. What is the change in the internal energy of the gas along path *CD*?



A) – 2.0 J
B) + 2.0 J
C) – 12 J
D) + 12 J
E) – 18 J

Ans:

For a cycle: $\Delta E_{int} = 0$

$$\Delta E_{AB} + \Delta E_{BC} + \Delta E_{CD} + \Delta E_{DE} + \Delta E_{EA} = 0$$

$$\Delta E_{AB} = \Delta E_{DE} = 0 \text{ (isothermal)}$$

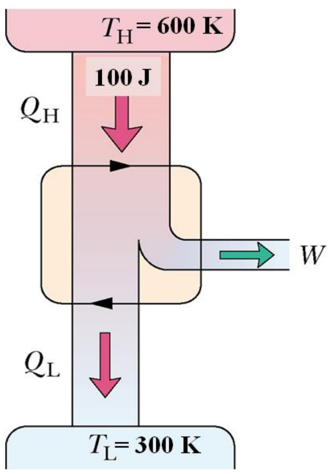
$$\Rightarrow \Delta E_{CD} = -\Delta E_{BC} - \Delta E_{EA}$$

$$= W_{BC} - \Delta E_{EA}$$

$$= 8.0 - 10 = -2.0 \text{ J}$$

Q17.

A real heat engine is represented by the diagram shown in **Figure 5**. The heat expelled to the low-temperature reservoir can be



A) 60 J
B) 40 J
C) 20 J
D) 10 J
E) zero

Ans:

Carnot: $W = \varepsilon_c . Q_H = 0.5 \times 100 = 50 \text{ J}$

$W = \varepsilon_c . Q_H = 0.5 \times 100 = 50 \text{ J}$

$$Q_L = Q_H - W = 100 - 50 \text{ J} = 50 \text{ J}$$

A real heat engine will have less efficiency

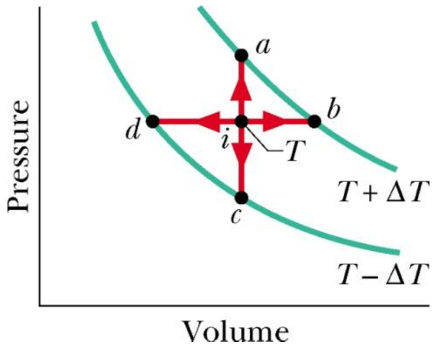
$\therefore$ Less work and more Q_L

$\therefore \; Q_L > 50 \text{ J}$

Q18.

Point ***i*** in **Figure 6** represents the initial state of an ideal gas at temperature *T*. Rank the entropy changes that the gas undergoes as it moves reversibly from point ***i*** to points *a*, *b*, *c*, and *d*, greatest first.

Figure # 6



A) *b, a, c, d*
B) *a, b, c, d*
C) *b, d, a, c*
D) (*b* and *d* tie), (*a* and *c* tie)
E) (*b* and *d* tie), *a*, *c*

Ans:

$$\Delta S = \int \frac{dQ}{T} = \int \frac{nC.dT}{T}$$

$$\text{isobaric: } \Delta S = n.C_p.\,ln\left(\frac{T_f}{T_i}\right)$$

$$\text{isochoric: } \Delta S = n.C_v.\,ln\left(\frac{T_f}{T_i}\right)$$

Q19.

In an experiment, 200 g of aluminum at 100 °C is mixed with 200 g of water at 20 °C. The final equilibrium temperature is 34 °C. What is the change in entropy of the aluminum-water system? The specific heat of aluminum is 900 J/kg.K.

A) + 4.1 J/K
B) + 74 J/K
C) – 74 J/K
D) – 4.1 J/K
E) zero

Ans:

$$\Delta S_{Al} = 0.2 \times 900 \times \ln\left(\frac{34+273}{100+273}\right) = -35.051\ \frac{J}{K}$$

$$\Delta S_{w} = 0.2 \times 4190 \times \ln\left(\frac{34+273}{20+273}\right) = +39.114\ \frac{J}{K}$$

$$\Delta S_{system} = \Delta S_{Al} + \Delta S_{w} = +4.063 \rightarrow +4.1\ \frac{J}{K}$$

Q20.

A Carnot refrigerator operates between two reservoirs at – 3.0 °C and 27 °C. How long should the refrigerator be operated, with a 500 W power input, in order for it to absorb 4500 J of heat from the cold reservoir?

A) 1.0 s
B) 5.0 s
C) 2.7 s
D) 6.3 s
E) 1.6 s

Ans:

$$K = \frac{T_L}{T_H - T_L} = \frac{270}{30} = 9$$

$$K = \frac{Q_L}{W} \rightarrow W = \frac{Q_L}{K} = \frac{4500}{9} = 500\ J$$

$$W = P.t \ \rightarrow t = \frac{W}{P} = \frac{500}{500} = 1.0\ s$$
