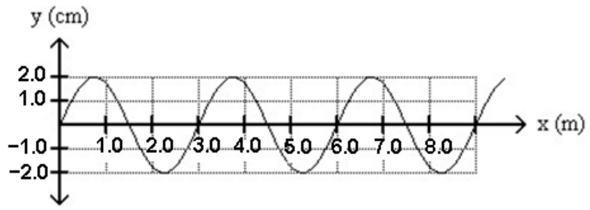
Q1.

A transverse wave travelling along a string (x-axis) has a form given by equation $y = y_m \sin(kx - \omega t)$. **FIGURE 1** shows the displacement of string elements as a function of x. Find the angular wave number *k* of the wave.

Figure 1



A) 2.1 m^{-1}
B) 0.70 m^{-1}
C) 4.2 m^{-1}
D) 3.0 m^{-1}
E) 9.0 m^{-1}

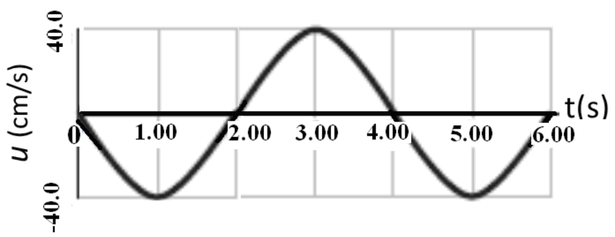
Ans:

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{3} = 2.094/m$$

Q2.

FIGURE 2 shows the transverse velocity *u* versus t of the point on a string at x = 0 cm as a sinusoidal wave passes through it. Find the amplitude y_m of the wave

Figure 2



A) 25.5 cm
B) 40.0 cm
C) 51.0 cm
D) 12.2 cm
E) 80.0 cm

Ans:

$$u_{max} = \omega y_m$$

From the graph $u_{max} = 0.4 m/s$ $\omega = \frac{2\pi}{T} = \frac{2\pi}{4} = 1.57 rad/s$

Therefore

$$0.4 = 1.57 \times y_m$$

$$y_m = 0.255m = 25.5cm$$

Q3.

What phase difference, in terms of wavelength λ, between two identical traveling waves, moving in the same direction along a stretched string, results in a combined wave having an amplitude 1.50 times that of the common amplitude of the two combining waves?

A) 0.23λ
B) 0.12λ
C) 0.50λ
D) 0.70λ
E) 1.50λ

Ans:

$$1.5y_m = 2y_m \cos(\phi/2)$$

$$\cos(\phi/2) = \frac{1.5}{2}$$

$$\phi = 2 \times 41.4 = 82.82^o$$

$$180° = \frac{\lambda}{2}$$

$$82.82° = \frac{82.82}{180} \cdot \frac{\lambda}{2}$$

$$82.82° = 0.23\,\lambda$$

Q4.

A vibrating source generates a sinusoidal wave of constant frequency in a string under constant tension. If the power delivered to the string is doubled which of the following statements is **TRUE**? (v is the wave speed and y_m is the wave amplitude)

A) v remains constant and y_m increased by a factor of $\sqrt{2}$.
B) v decreased by a factor of 2 and y_m is increased by a factor of 2.
C) v increased by a factor of 2 and y_m is decreased by a factor of $\sqrt{2}$.
D) v remains constant and y_m is decreased by a factor of $\sqrt{2}$.
E) v remains constant and y_m is increased by a factor of 2.

Ans:

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

$$y_{m-A} = 2y_{m-B}$$

$$P_A = 4P_B$$

$$\mathrm{v} = \sqrt{\frac{\tau}{\mu}};\ \mu = constant, \tau = constant$$

$$\Rightarrow\ \mathrm{v} = \mathrm{constant}$$

Q5.

A string fixed at both ends is under a tension of 360 N. One of its resonance frequencies is 375 Hz. The next higher resonance frequency is 450 Hz. What is the fundamental frequency of this string?

A) 75.0 Hz
B) 300 Hz
C) 225 Hz
D) 413 Hz
E) 150 Hz

Ans:

$$f_n = \frac{nv}{2L} \Rightarrow 375 = \frac{nv}{2L}$$

$$f_{n+1} = \frac{(n+1)v}{2L} \Rightarrow 425 = \frac{nv}{2L} + \frac{v}{2L}$$

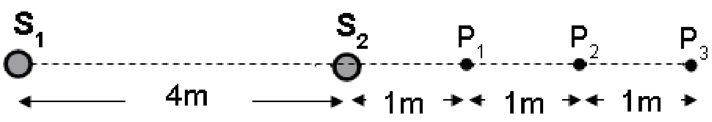
$$f_{n+1} - f_n = 425 - 375 = \frac{v}{2L}$$

$$75 = \frac{v}{2L} = f_1$$

Q6.

Two in phase point sources S_1 and S_2 placed 4 m apart emit identical sound waves of wavelength 2 m. A detector placed at points P_1, P_2, and P_3along the line joining S_1S_2shown in **FIGURE 3,** will detect

Figure 3



A) maximum intensity at all three points P_1, P_2, and P_3
B) maximum intensity at P_2 and minimum intensity at both P_1 and P_3
C) minimum intensity at both P_1 and P_2, and maximum intensity at P_3
D) maximum intensity at both P_1 and P_3, and minimum intensity at P_2
E) maximum intensity at P_1 and minimum intensity at both P_2 and P_3

Ans:

A

path difference for all point p_1, p_2, p_3 *is* $|s_1 s_2|$

$|s_1 s_2| = 4m = 2\lambda$

Q7.

A two-open ends pipe is 78.0 cm long. Third harmonic of the two-open ends pipe is equal to fundamental frequency of a one-open end pipe. How long is the one-open end pipe?

A) 13.0 cm
B) 26.0 cm
C) 34.0 cm
D) 78.0 cm
E) 156 cm

Ans:

$$f_{n,2-open} = \frac{nv}{2L}$$

$$f_{n,1-open} = \frac{nv}{4L'}$$

$$f_{1,1-open} = f_{3,2-open}$$

$$\frac{v}{4L'} = \frac{3v}{2L'}$$

$$\frac{1}{2L'} = \frac{3}{78} \Rightarrow L' = 13cm$$

Q8.

A spherical point source radiates sound uniformly in all directions. At a distance of 10 m from the source, the sound intensity level is 80 dB. At what distance from the source is the intensity level 60 dB?

A) 0.10 km
B) 100 km
C) 10.0 km
D) 0.12 km
E) 0.01km

Ans:

$$\Delta\beta = \beta_2 - \beta_1 = 10\ dB log\ \frac{I_2}{I_1}$$

$$80 - 60 = 10\ dB log\ \frac{\frac{P_S}{4\pi r_2^2}}{\frac{P_S}{4\pi r_1^2}} = 10 dB log\left(\frac{r_1^2}{r_2^2}\right)$$

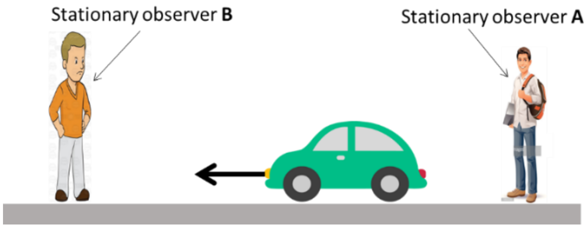
$$2 = log\frac{r_1^2}{(10)^2} \Rightarrow 10^2 = \frac{r_1^2}{(10)^2} \Rightarrow r_1^2 = 10^4$$

$$r_1 = 10^2 = 100\ m = 0.10\ km$$

Q9.

A car is travelling from a stationary observer **A** towards another stationary observer **B**, as shown in the **Figure 4**. The observer **A** hears a sound of frequency 747 Hz and the observer **B** hears a sound of frequency 863 Hz from the car horn. How fast is the car traveling?

Figure 4



A) 24.7 m/s
B) 46.0 m/s
C) 50.4 m/s
D) 20.0 m/s
E) 75.6 m/s

Ans:

$$747 = f\,\frac{V}{V+V_c}\,;863 = f\,\frac{V}{V-V_c}$$

$$\frac{747}{863} = \frac{\frac{V}{V+V_c}}{\frac{V}{V-V_c}} \Rightarrow \frac{747}{863} = \frac{V-V_c}{V+V_c}$$

$$863\,V - 863\,V_c = 747(V+V_c) \Rightarrow\ 863\,V - 747\,V =\ 863\,V_c + 747\,V_c$$

$$\frac{863-747}{863+747}\cdot V =\ V_c$$

$$\frac{116}{1616}\cdot V =\ V_c\ \ \Rightarrow V_c = \frac{116}{1616}\cdot 343 =\ \ 24.7\ m/s$$

Q10.

On a linear X temperature scale, water freezes at –120.0 ^{o}X and boils at 360.0^{o}X. On a linear Y temperature scale, water freezes at –70.00^{o}Y and boils at –30.00 ^{o}Y. A temperature of 50.0^{o}Y corresponds to what temperature of X scale.

A) 1320 ^{o}X
B) 20.00 ^{o}X
C) 1440^{o}X
D) 425.0 ^{o}X
E) 1560^{o}X

Ans:

$$\frac{X-MP}{BP-MP}=\frac{Y-MP}{BP-MP}$$

$$\frac{X-(-120)}{360-(-120)}=\frac{Y-(-70)}{-30-(-70)}$$

$$for\ Y=50$$

$$\frac{X+120}{480}=\frac{50-(-70)}{-30-(-70)}=\frac{120}{40} \qquad X=1320^{0}X$$

Q11.

512 g of a metal at a temperature of 15.0 ^{o}C is dropped into a thermally insulated 225 g copper container containing 325 g of water at 98.0 ^{o}C. A short time later, the system reaches its final equilibrium temperature of 78.0 ^{o}C. Find the specific heat of the metal (specific heat of copper 400 J/kg.K)

A) 900 J/kg.K
B) 645 J/kg.K
C) 788 J/kg.K
D) 200 J/kg.K
E) 440 J/kg.K

Ans:

Heat lost = heat gained

$$(mc\Delta T)_{water}+(mc\Delta T)_{Al}=(mc\Delta T)_{metal}$$

$$(0.325\times4190\times20)_{water}+(0.225\times400\times20)_{Al}=(0.512\times c(63)_{metal}$$

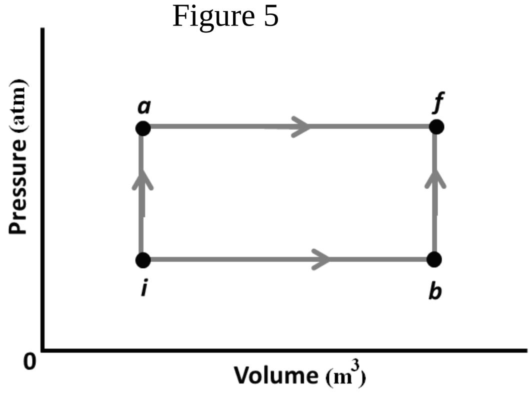
$$(27235)_{water}+(1800)_{Al}=(32.256c)_{metal}$$

$$c=29035/32.256=900J/kg.K$$

Q12.

When a system is taken from state *i* to state *f* along path *iaf* in **FIGURE 5**, Q = 50 cal and W = 20 cal. Along path *ibf*, Q =36 cal. What is W along path *ibf*?

Figure 5



A) +6.0 cal
B) +66cal
C) +20 cal
D) −6.0 cal
E) +3.0 cal

Ans:

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

Change in internal energy for *iaf* and *ibf* is same

$$(Q - W)_{iaf} = (Q - W)_{ibf}$$

$$50 - 20 = 36 - W$$

$$W = 6.0 cal$$

Q13.

A cylindrical copper rod of length 0.800 m and cross sectional area of 8.00 cm^2 is insulated along its side. One end of the rodis held in a water-ice mixture and the other end in a mixture of boiling water and steam. Calculate how much ice will melt in 10.0 min in the ice-water mixture (assume that not all the ice will melt in ice-water mixture) (thermal conductivity of copper 401 W/m.K)

A) 72.3 g
B) 523 g
C) 1.12 g
D) 12.0 g
E) 511 g

Ans:

$$P_C = \frac{KA\Delta T}{L} = \frac{401 \times 8 \times 10^{-4} \cdot 100}{0.8} = 40.1 \text{ J/S}$$

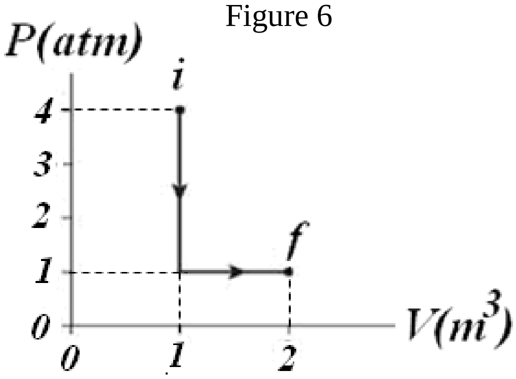
$$Q = mL_f$$

$$40.1 \times 10 \times 60 = m333 \times 10^3 \Rightarrow m = 0.07225 = 72.25\ g = 72.3\ g$$

Q14.

For a given mass of an ideal gas what is the ratio T_f/T_i for the process given in **FIGURE 6**

Figure 6



A) 1/2
B) 1/4
C) 1
D) 8
E) 4

Ans:

$$pV = nRT$$

$$p_i V_i = nRT_i \quad 4\times 1 = nRT_i$$

$$p_f V_f = nRT_f \quad 1\times 2 = nRT_f$$

Therefore $\dfrac{T_f}{T_i} = \dfrac{1}{2}$

Q15.

Air that initially occupies 0.140 m^3 at a pressure of 204.0 kPa is expanded isothermally to a pressure of 101.3 kPa and then cooled at constant pressure until it reaches its initial volume. Compute the work done by the air. (Assume air to be an ideal gas).

A) 5.62×10^3 J
B) 2.25×10^3 J
C) 3.40×10^4 J
D) 0
E) 1.32×10^4 J

Ans:

$$P_i V_i = P_f V_f \Rightarrow \frac{P_i}{P_f} = \frac{V_f}{V_i}$$

$$\Rightarrow V_f = \frac{204 \times 10^3}{101.3 \times 10^3} \times 0.140$$

$$V_f = \frac{1428}{5065} = 0.2819 m^3$$

$$W_{iso} = nRT ln \frac{V_f}{V_i}$$

$$= P_i V_i ln\left(\frac{P_i}{P_f}\right) = 204 \times 10^3 \times 0.140 \ln\left(\frac{204 \times 10^3}{101.3 \times 10^3}\right)(0.7000)$$

$$W_{iso} = 19992.96 = 19993\ J$$

$$W_2 = P \cdot \Delta V$$

$$= 101.3 \times 10^3 \times (0.2819 - 0.140) = 14378$$

$$W = W_{iso} - W_2$$

$$W_{net} = 5.62 \times 10^3\ J$$

Q16.

At a given temperature an ideal gas mixture consists of molecules of types 1, 2, and 3, with molecular masses $m_1 > m_2 > m_3$. Rank three types of molecules according to average translational kinetic energy K_{avg} and rms speed v_{rms}, **GREATEST FIRST**:

A) (K_{avg}) all tie ; (v_{rms}) 3,2,1
B) (K_{avg}) all tie ;(v_{rms}) 1,2,3
C) (K_{avg}) 1,2,3 ; (v_{rms}) 1,2,3
D) (K_{avg}) 1,2,3; (v_{rms}) 3,2,1
E) (K_{avg}) 3,2,1 ; (v_{rms}) 3,2,1

Ans:

$$A\ ;\ v_{r\cdot m\cdot s} = \sqrt{\frac{3RT}{M}};\ K_{avg} = \frac{3}{2}K_T$$

Q17.

A 2.00 mol sample of a diatomic ideal gas expands adiabatically from an initial temperature T_i, a pressure of 5.00 atm and a volume of 12.0 L to a final volume of 30.0 L. What is the final temperature of the gas?

A) 253 K
B) 366K
C) 185K
D) 425K
E) 310K

Ans:

$$r = \frac{C_p}{C_v} = \frac{\frac{7}{2}}{\frac{5}{2}} = \frac{7}{5}$$

$$PV = nRT \Rightarrow T = \frac{PV}{nR}$$

$$T_i(V_i)^{r-1} = T_f(V_f)^{r-1}$$

$$\left(\frac{P_iV_i}{nR}\right)(V_i)^{r-1} = (T_fV_f)^{r-1}$$

$$\left(\frac{5 \times 1.01 \times 10^5 \times (12 \times 12)}{2 \times 8.31}\right) = (T_f 30)^{\frac{2}{5}}$$

$$\frac{5 \times 1.01 \times 10^5 \times 12}{2 \times 8.31}\left(\frac{12}{30}\right)^{\frac{2}{5}} = T_f \Rightarrow T_f = 253\ K$$

Q18.

200 g of aluminum at 100 °C is mixed with 50.0 g of water at 20.0 °C, with the mixture thermally insulated. What is the entropy change of the aluminum-water system? (The specific heat of aluminum is 900 J/kg.K and the specific heat of water is 4.19 x 10^3 J/kg.K.)

A) +2.83 J/K
B) 0
C) −3.23 J/K
D) −9.14 J/K
E) +7.12 J/K

Ans:

$$0.2 \times 900 \times (100 - T_f) = 0.05 \times 4190(T_f - 20)$$

$$18000 - 180\ T_f = 209.5\ T_f = 4190$$

$$18000 + 4190 = (209.5 + 180)\ T_f$$

$$T_f = 56.97 = 57℃$$

$$T_f = 330\ k;\ \Delta s = mcln\ \frac{T_f}{T_i}$$

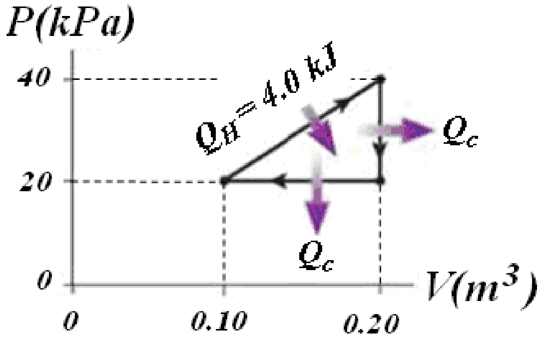
$$\Delta S_{sys} = \Delta S_w + \Delta S_{Al}$$

$$\Delta S = 0.05 \times 4190 \ln\left(\frac{330}{293}\right) + 0.2 \times 900\ ln\left(\frac{330}{373}\right) = +2.83\ \ J/K$$

Q19.

What is the efficiency of the heat engine shown in **FIGURE 7?**

Figure 7



A) 0.25
B) 0.50
C) 0.10
D) 4.0
E) 0.60

Ans:

W_{out} = area under the graph

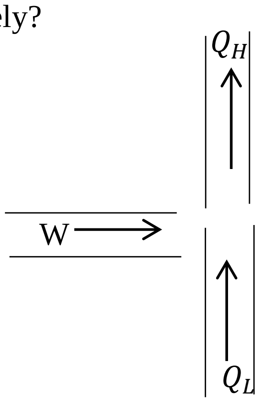
$$W_{out} = \frac{1}{2}(0.1)(20000) = 1000J$$

$$\varepsilon = \frac{W_{out}}{Q_{in}} = \frac{1000}{4000} = 0.25$$

Q20.

50.0 J of work is done per cycle on a refrigerator with coefficient of performance of 4.00. How much heat is extracted from the cold reservoir and exhausted to the hot reservoir per cycle by the refrigerator, respectively?

A) 200 J and 250 J
B) 200 J and 150 J
C) 100 J and 150 J
D) 100 J and 50.0 J
E) 50.0 J and 100 J



Ans:

$W = 50\ \text{J}, K = 4.00$

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

$$4 = \frac{Q_L}{50} \Rightarrow Q_L = 200\ J$$

$$Q_H = W + Q_L = 50 + 200 = 250\ J$$