**Q1.**

A sinusoidal wave travels along a stretched string. The time for a particular point to move from maximum displacement to zero is 0.17 s. If the wavelength of the wave is 1.8 m what is the wave speed?

    A) 2.65 m/s
    B) 10.6 m/s
    C) 1.23 m/s
    D) 3.96 m/s
    E) 7.45 m/s

**Ans:**

$$T = 0.17 \times 4 = 0.68 \; s$$

$$V = f\lambda = \frac{\lambda}{T} = \frac{1.8}{0.68}$$

$$V = 2.647 \cong 2.65 \; m/s$$

**Q2.**

Two string, 1 and 2, are made of same material but area of cross-section of string 2 is twice of that the string 1. Both strings are under same tension. The string 1 transmits an average power $P_1$ if a wave with frequency $\omega$ and amplitude $y_m$ is travelling along it. Find the average power transmitted along the string 2 if the same wave (of frequency $\omega$ and amplitude $y_m$) passes through the string 2.

    A) 1.4 $P_1$
    B) 2.0 $P_1$
    C) 2.8 $P_1$
    D) $P_1$
    E) 3.5 $P_1$

**Ans:**

$$P_1 = \frac{1}{2}\mu_1\omega^2 y_m^2 v_1$$

$$\mu_2 = 2\mu_1; \; v_2 = \sqrt{\frac{\tau}{\mu_2}} = \frac{1}{\sqrt{2}} v_1$$

$$P_2 = \frac{1}{2}2\mu_1\omega^2 y_m^2 \frac{1}{\sqrt{2}} v_1$$

$$P_2 = \frac{2}{\sqrt{2}}\left[\frac{1}{2}\mu_1\omega^2 \tau_m^2 \; v_1\right] = \sqrt{2}P_1 v_1 \approx 1.4 \; P_1$$

**Q3.**

A wave in a string is given by the equation:
$$y(x,t) = 0.240\sin(3.00x - 24.0t),$$

Where x and y are in meters and t is in seconds. Calculate the magnitude of the transverse acceleration of the string element at x = 2.00 m and t = 1.00 s.

A) 104 m/s$^2$
B) 49.3 m/s$^2$
C) 91.3 m/s$^2$
D) 57.7 m/s$^2$
E) 124 m/s$^2$

**Ans:**

$$v = 0.24(-24)\cos(3x - 24t)$$

$$a = 0.24(-24)^2\left(-\sin(3x - 24t)\right) = (24)^2(0.24)\sin(3 \times 2 - 24 \times 1)$$

$$a = -\frac{3456}{25}\sin(-18) = -103.816 \approx 104 \ m/s^2$$

**Q4.**

A rope, under a tension of 400 N and fixed at both ends, oscillates in a second-harmonic standing wave pattern. The displacement of the rope is given by:
$$y = (0.10 \text{ m}) (\sin \pi x/2) (\sin 12\pi t)$$

Where x = 0 at one end of the rope, x and y is in meters, and t is in seconds. What is the mass per unit length of the rope?

A) 0.694 kg/m
B) 3.78 kg/m
C) 0.356 kg/m
D) 9.24 kg/m
E) 0.243 kg/m

**Ans:**

$$v = \sqrt{\frac{\tau}{\mu}} \Rightarrow \mu = \frac{\tau}{v^2}$$

$$v = \frac{\omega}{k} = \frac{12\pi}{\frac{\pi}{2}} = 24 \ m/s$$

$$\mu = \frac{\tau}{V^2} = \frac{400}{(24)^2} = \frac{25}{36} \approx 0.694 \ kg/m$$

**Q5.**

Strings A and B have identical lengths and linear densities, but string A is under greater tension than string B. **Figure 1** shows four situations, in which standing wave patterns exist on the two strings. In which situation(s) is there the possibility that strings A and B are oscillating at the same resonant frequency?

**Figure 1**

A) a and b
B) a, b, and c
C) d only
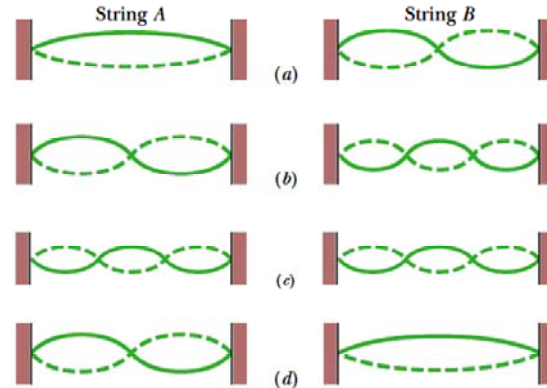D) c only
E) a and d



**Ans:**

$$v = \sqrt{\frac{\tau}{\mu}}$$

$$v_A > v_B$$

$$f_{nA} = \frac{n_A v_A}{2L}, f_{nB} = \frac{n_B v_B}{2L}$$

$$\frac{n_A v_A}{2L} = \frac{n_B v_B}{2L}$$

**Q6.**

A sound wave in air produces a pressure variation given by

$$\Delta p(x,t) = 0.75 \cos[\frac{\pi}{2}(x - 343t)]$$

Where p is in pascal, x and t are in meters and seconds, respectively. What is the displacement amplitude $s_m$ for the sound wave if the air density is 1.21 kg/m³?

A) $3.35 \times 10^{-6}$ m
B) $5.27 \times 10^{-6}$ m
C) $1.81 \times 10^{-6}$ m
D) $2.16 \times 10^{-6}$ m
E) $7.59 \times 10^{-6}$ m

**Ans:**

$$\Delta P = \rho v \omega S_m$$

$$0.75 = 1.21 \times 343 \left(\frac{343\pi}{2}\right) S_m$$

$$S_m = \frac{0.75}{1.21 \times (343)^2 \cdot \frac{\pi}{2}} = 3.35 \times 10^{-6}m$$

**Q7.**

**Figure 2a** A loudspeaker at X produces sound waves of frequency 171 Hz. The sound waves enter the tube and the sound energy is devided equally before travelling along the fixed and movable tubes. Intially the distance $d_1 = d_2$ (**Figure 2a**), then the moveable tube is slowly pulled out as shown in **Figure 2b**, find the $d_2 - d_1$ for which the microphone at Y detects first minima in sound intensity.



Figure 2a     Figure 2b

A) 0.50 m
B) 1.0 m
C) 2.0 m
D) 1.5 m
E) 0.25 m
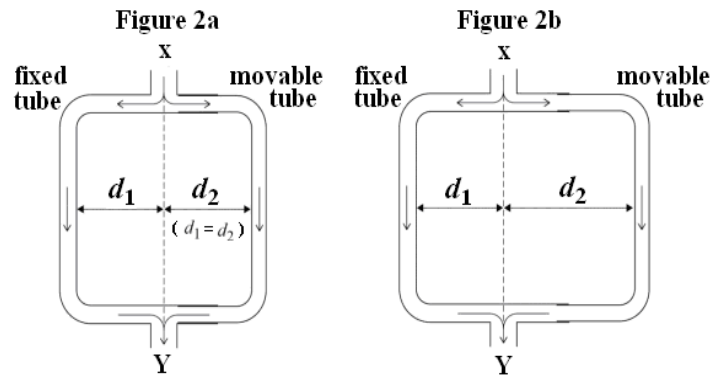
**Ans:**

For first minima total path difference required is $\dfrac{\lambda}{2} \Rightarrow 2\Delta L = \dfrac{\lambda}{2}$

$$\therefore d_2 - d_1 = \frac{\lambda}{4}$$

$$v = f\lambda \Rightarrow \lambda = \frac{V}{f} = \frac{343}{171}$$

$$d_2 - d_1 = \frac{1}{4}\frac{343}{171} = 0.50 \ m$$

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**Q8.**

A well with vertical sides and water at the bottom resonates at 9.00 Hz and at no lower frequency. Find the depth of the well. (Speed of sound in air 343 m/s)

A) 9.53 m
B) 20.1 m
C) 15.3 m
D) 6.52 m
E) 2.69 m

**Ans:**

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

$$f_1 = \frac{v}{4L} \Rightarrow 9 = \frac{343}{4L}$$

$$L = \frac{343}{36} \approx 9.53 \ m$$

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**Q9.**

A block with a speaker fixed to it, is connected to a spring and oscillating on a frictionless surface, as shown in **Figure 3**. The speaker emits sound waves of frequency 440 Hz. If the maximum speed of the block during oscillation is 20 m/s find the minimum frequency recorded by the observer standing in front of the speaker.

**Figure 3**

A) 416 Hz
B) 467 Hz
C) 250 Hz
D) 376 Hz
E) 440 Hz

**Ans:**

$$f' = f \frac{v + 0}{v + v_s}$$

$$f' = 440 \frac{343}{343 + 20} = 415.76 \approx 416 \text{ Hz}$$

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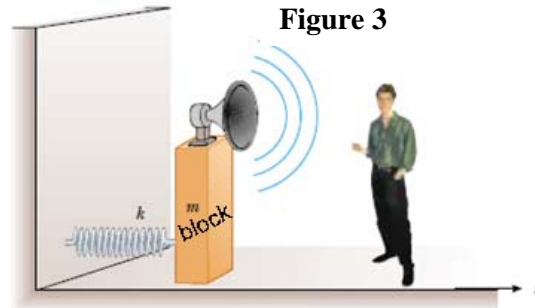
**Q10.**

The brass and aluminum bars shown in **Figure 4** are attached to fixed walls. At 27 °C the air gap between the rods is $1.3 \times 10^{-3}$ m. At what temperature will the gap be closed? (Coefficient of linear expansion of brass and aluminum are $19 \times 10^{-6}$ /C° and $23 \times 10^{-6}$ /C°, respectively)

**Figure 4**
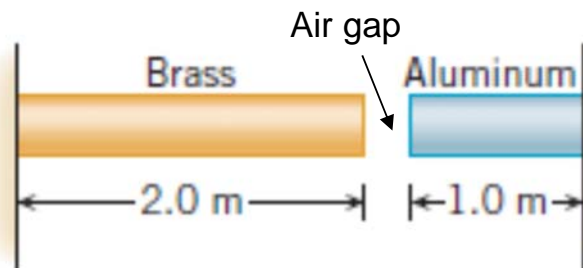
A) 48 °C
B) 60 °C
C) 35 °C
D) 72 °C
E) 57 °C

**Ans:**

$$\Delta L_{bra} + \Delta L_{Al} = 1.3 \times 10^{-3}$$

$$(\alpha_b 2 + \alpha_{Al} 1)\Delta T = 1.3 \times 10^{-3}.$$

$$(38 \times 10^{-6} + 23 \times 10^{-6})(T - 27) = 1.3 \times 10^{-3}$$

$$T - 27 = \frac{1.3 \times 10^{-3}}{61 \times 10^{-6}} = \frac{2947}{61} \cong 48°C$$

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**Q11.**

What mass of steam initially at 100 °C is needed to warm 200 g of water (in a thermally isolated container) from 20.0 °C to 50.0 °C? (Assume container has negligible heat capacity)

A) 10.2 g
B) 11.2 g
C) 6.72 g
D) 15.2 g
E) 13.2 g

**Ans:**

$$m_w C \Delta T = m_s L_v + m_s C \Delta T$$

$$0.2 \times 4190 \times 30 = m_s(2256 \times 10^3 + 4190 \times 50)$$
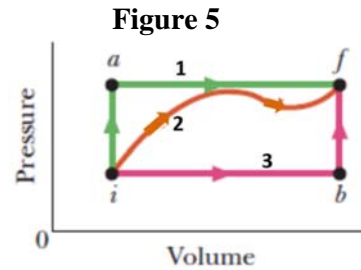
$$m_s = \frac{25140}{2465500} = 0.01019 \cong 10.2 \ g$$

**Q12.**

An ideal gas is taken from state $i$ to state $f$ along three different paths as shown in **Figure 5**. Rank the heat exchanged with the environment for the three paths, 1 (*iaf*), 2 (*if*), and 3 (*ibf*), **GREATEST FIRST**.

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

**Ans:**

**A**

**Figure 5**

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c-20-n-20-s-0-e-1-fg-1-fo-0

**Q13.**

A cylindrical metal rod of a length 1.2 m and cross-sectional area 4.2 cm$^2$ is insulated along its side. One end of the rod is in ice-water mixture and other end is in a mixture of a boiling water and steam. If the ice in ice-water mixture melts at a rate of 20 mg/s find the thermal conductivity of the metal.

A) 190 W/m.K
B) 122 W/m.K
C) 234 W/m.K
D) 319 W/m.K
E) 167 W/m.K

**Ans:**

$$P = \frac{K A \Delta T}{\Delta L}$$

$$20 \times 10^{-3} \times 333 = \frac{K \times 4.2 \times 10^{-4} \times 100}{1.2}$$

$$K = \frac{6.66 \times 1.2}{4.2 \times 10^{-2}} = 190.29 \cong 190 \ W/m \cdot K$$

**Q14.**

**Figure 6** shows a thermodynamics process followed by 2.00 moles of an ideal gas. Calculate the heat energy absorbed by the gas during the process 2 to 3.

A) 5.43 × 10$^4$ J
B) 1.09 × 10$^4$ J
C) 7.29 × 10$^4$ J
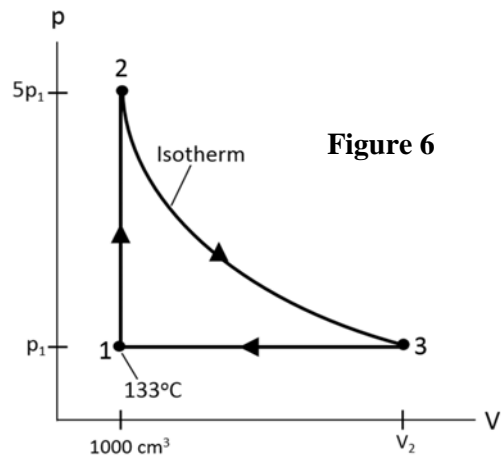D) 3.71 × 10$^4$ J
E) 6.81 × 10$^4$ J

**Ans:**

$$5P_1V_1 = P_1V_2 \Rightarrow \frac{V_2}{V_1} = 5$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_3} \Rightarrow T_3 = \frac{V_2}{V_1}T_1$$

$$T_3 = 5 \times (133 + 273) = 2030 \ K$$

$$Q = W$$

$$= nRT \ln \frac{V_f}{V_i} = 2 \times 8.31 \times 2030 \ln 5 = 5.43 \times 10^4 \ J$$

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c-20-n-20-s-0-e-1-fg-1-fo-0

**Q15.**

At what temperature do *atoms of helium* gas have the same rms speed as *molecules of hydrogen* gas at 20 ºC? (Molar mass of H and He is 1.0 g/mole and 4.0 g/mole, respectively)

A) 313 ºC
B) 980 ºC
C) 785 ºC
D) 120 ºC
E) 260 ºC

**Ans:**

$$V_{r.m.s} = \sqrt{\frac{3RT}{M}}$$

$$V_H = V_H$$

$$\sqrt{\frac{3R(20+273)}{2}} = \sqrt{\frac{3R(T)}{4}}$$

$$T = 293 \times 2 = 586K = 313°C$$

**Q16.**

When 21.0 J are added as heat to an ideal gas, the volume of the gas changes from 5.00 cm³ to 100 cm³ while the pressure remains at 1.00 atm. Find the molar specific heat $C_p$ of the gas.

A) 18.2 J/mol.K
B) 12.2 J/mol.K
C) 21.7 J/mol.K
D) 16.7 J/mol.K
E) 27.7 J/mol.K

**Ans:**

$$Q = nC_p\Delta T$$

$$P\Delta V = nR\Delta T$$

$$Q = nC_p \cdot \frac{P\Delta V}{nR}$$

$$C_p = \frac{Q \cdot R}{P \cdot \Delta V} = \frac{21 \times 8.31}{1.01 \times 10^5 \times 95 \times 10^{-6}} = 18.18 \ J/mol \cdot K$$

*Q17.*

A 0.005 mol of monatomic gas expands adiabatically from an initial pressure of 5.00 atm and temperature of 500 K to a final pressure of 1.00 atm. Find the work done by the gas.

   A) +14.8 J
   B) −14.8 J
   C) −9.27 J
   D) +9.27 J
   E) −11.4 J

**Ans:**

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

$$\Delta E_{int} = -W \Rightarrow W = -nC_v\Delta T$$

$$T_1^r P_1^{1-r} = T_2^r P_2^{1-r}$$

$$(500)^{\frac{5}{3}} \left(\frac{5}{1}\right)^{1-\frac{5}{3}} = T_2^{\frac{5}{3}} \Rightarrow T_2 = 262.65$$

$$\omega = -\left[0.005 \times \frac{3}{2} \times 8.31(262.65 - 500 - 237)\right]$$

$$= 0.005 \times 1.5 \times 8.31 = 14.79 \text{ J}$$

**Q18.**

A 0.500 kg copper block, with an initial temperature of 130 °C, dropped into a lake whose temperature is 15.0 °C. What is the entropy change of the lake? (The specific heat of copper is 386 J/kg.K.)

   A) +77.1 J/K
   B) −77.1 J/K
   C) 0
   D) −105 J/K
   E) +836 J/K

**Ans:**

$$\Delta S = \frac{\Delta Q}{T}$$

$$= \frac{(mc\Delta T)cu}{T} = \frac{0.5 \times 386 \times 115}{(15 + 273)} = 77.1 \text{ J}/K$$

**Q19.**

A 600 W Carnot engine operates between 100 ºC and 60.0 ºC. What is the rate at which energy is exhausted by the engine as heat?

    A) 5.00 kJ/s
    B) 0.672 kJ/s
    C) 4.40 kJ/s
    D) 0.0720 kJ/s
    E) 5.61 kJ/s

**Ans:**

$$\varepsilon = 1 - \frac{T_L}{T_H} = 1 - \frac{333}{373} = \frac{40}{373}$$

$$\varepsilon = \frac{\omega}{Q_H} \Rightarrow Q_H = \frac{600}{40/373} = 5795 \text{ J}$$

$$\omega = Q_H - Q_L \Rightarrow Q_L = Q_H - \omega = 4995 \text{ J} = 5.00 \times 10^3 \text{ J}$$

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**Q20.**

Which of the following statements is true about the entropy per cycle for (a) Carnot refrigerator, (b) a real refrigerator, and (c) a perfect refrigerator (an imaginary refrigerator)?

    A) (a) remains constant, (b) increases, (c) decreases
    B) (a) remains constant, (b) increases, (c) remains constant
    C) (a) increases, (b) decreases, (c) remains constant
    D) (a) decreases, (b) decreases, (c) decreases
    E) (a) increases, (b) increases, (c) increases

**Ans:**

    A