**Q1.**

Under a tension $\tau$, it takes 2 s for a pulse to travel the length of a stretched wire. What tension is required for the pulse to take 6 s to travel the length of the wire?

A) $\tau/9$
B) $\tau/3$
C) $\tau$
D) $3\tau$
E) $9\tau$

**Ans:**

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

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

$$t_2 = \frac{L\sqrt{\mu}}{\sqrt{\tau_2}} \; ; \; t_1 = \frac{L\sqrt{\mu}}{\sqrt{\tau_1}}$$

$$\frac{t_2}{t_1} = \sqrt{\frac{\tau_1}{\tau_2}}$$

$$\Rightarrow \tau_2 = \left(\frac{t_1}{t_2}\right)^2 . \tau_1$$

$$= \left(\frac{2}{6}\right)^2 . \tau = \tau/9$$

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**Q2.**

A transverse sinusoidal wave, travelling on a stretched string, is described by the equation: $y\,(x,t) = y_m \sin\,(kx - \omega t + \phi)$. At time $t = 0$, the point on the string at $x = 0$ has positive displacement and is moving upward. Then:

A) $\pi/2 < \phi < \pi$
B) $0 < \phi < \pi/2$
C) $\pi < \phi < 3\pi/2$
D) $3\pi/2 < \phi < 2\pi$
E) All the other answers are possible.

**Ans:**

$$y(x,t) = y_m.\sin(kx - \omega t + \phi) \rightarrow y(0,0) = y_m.\sin\phi \rightarrow \sin\phi +$$

$$u(x,t) = -\omega y_m.\cos(kx - \omega t + \phi) \rightarrow u(0,0) = -\omega y_m.\cos\phi \rightarrow \cos\phi -$$

$\therefore$ $\phi$ must be in the second quadrant

---

**Q3.**

Two sinusoidal waves, identical except for phase, travel in the same direction along a stretched string, producing a resultant wave *y' (x,t) = 0.050 sin (15x – 2.4t + 0.78)*, where *x* is in meters and *t* is in seconds. What is the amplitude of the interfering waves?

A) 0.035 m
B) 0.10 m
C) 0.025 m
D) 0.027 m
E) 0.050 m

**Ans:**

$$y' = \left(2y_m \cos\frac{\phi}{2}\right).\sin(kx - \omega t + \phi/2)$$

$$\Rightarrow \frac{\phi}{2} = 0.78 \text{ rad} \implies \cos\frac{\phi}{2} = 0.71$$

$$y_m = \frac{0.050}{2 \times 0.71} = 0.035 \text{ m}$$

---

**Q4.**

The speed of waves on a string fixed at both ends is 180 m/s. The string is vibrating in the third harmonic with a frequency of 240 Hz. The amplitude of the standing wave at an antinode is 0.48 cm. Calculate the amplitude of the standing wave at a point which is at a distance of 50 cm from the left end of the string.

A) 0.42 cm
B) 0.37 cm
C) 0.15 cm
D) 0.48 cm
E) 0.24 cm

**Ans:**

$$y = 2y_m.\sin k_x.\cos\omega t$$

$$\text{antinode: amplitude} = 2y_m$$

$$\therefore y_m = 0.24 \text{ cm}$$

$$\lambda = \frac{v}{f} = \frac{180}{240} = 0.75 \text{ m}$$

$$\therefore k = \frac{2\pi}{\lambda} = 8.377 \text{ m}^{-1}$$

$$\text{Amplitude} = 2y_m.\sin kx$$

$$= 0.48 \times \sin(8.377 \times 0.5) = 0.42 \text{ cm}$$

---

**Q5.**

If the intensity of a sound source is doubled, what will be the increase in sound level?

A) 3.0 dB
B) 2.0 dB
C) 4.0 dB
D) 1.4 dB
E) 100 dB

**Ans:**

$$\beta_1 = 10.\log\left(\frac{I_1}{I_0}\right)$$

$$\beta_2 = 10.\log\left(\frac{I_2}{I_0}\right)$$

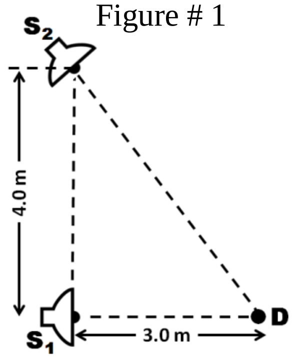
$$\Delta\beta = \beta_2 - \beta_1 = 10.\left[\log\left(\frac{I_2}{I_0}\right) - \log\left(\frac{I_1}{I_0}\right)\right] = 10.\log\left(\frac{I_2}{I_1}\right) = 10.\log 2 = 3.0\text{ dB}$$

---

**Q6.**

Two sound sources (S1 and S2) are driven by the same generator, and emit sound waves in phase. The two sources and a detector (D) are arranged as shown in **FIGURE 1.** What is the lowest frequency that results in destructive interference at the detector location? Take the speed of sound in air as 340 m/s.

Figure # 1




A) 85 Hz
B) 260 Hz
C) 170 Hz
D) 430 Hz
E) 236 Hz

**Ans:**

$$L_1 = 3.0\text{ m};\quad L_2 = 5.0\text{ m} \quad\Rightarrow\quad \Delta L = L_2 - L_1 = 2.0\text{ m}$$

$$\text{Destructive interference: } \Delta L = \frac{(2n+1)\lambda}{2}$$

$$\text{or: } \Delta L = \frac{(2n+1)v}{2f}$$

$$\therefore f = \frac{(2n+1)v}{2\Delta L}$$

$$\text{Lowest} \longrightarrow n = 0$$

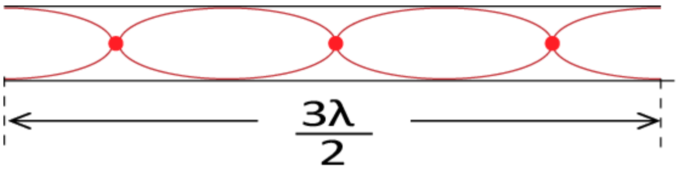
$$\therefore f = \frac{v}{2\Delta L} = \frac{340}{4.0} = 85\text{ Hz}$$

---

**Q7.**

Standing sound waves are produced in a pipe that is open at both ends, and has a length of 1.2 m. For the third harmonic standing wave, at what distance from either end is the first pressure antinode?

A) 0.20 m
B) 0.40 m
C) 0.80 m
D) 0.30 m
E) 1.8 m




**Ans:**

Pressure antinode = displacement node

$$\lambda_n = \frac{2L}{n} \Rightarrow \lambda_3 = \frac{2 \times 1.2}{3} = 0.8 \text{ m}$$

$$d = \frac{\lambda}{4} = \frac{0.8}{4} = 0.20 \text{ m}$$

**Q8.**

An ambulance emits sound waves with frequency $f_o$. A stationary observer detects a frequency of 1.05 $f_o$ as the ambulance approaches him. What is the speed of the ambulance? Take the speed of sound as 343 m/s.

A) 16.3 m/s
B) 36.1 m/s
C) 32.7 m/s
D) 28.7 m/s
E) 11.3 m/s

**Ans:**

$$f' = f_0 \frac{v}{v - x} \text{ ; x is speed of ambulance}$$

$$\text{Away: } 1.05 f_o = f_0 \frac{v}{v - x}$$

$$1.05 \text{ v} - 1.05 \text{ x} = \text{v}$$

$$0.05\text{v} = 1.05\text{x}$$

$$\Rightarrow x = \frac{0.05 \text{ v}}{1.05} = \frac{0.05 \times 343}{1.05} = 16.3 \text{ m/s}$$

**Q9.**

A temperature scale (X) is defined so that its zero is the absolute zero. The size of one degree on the X scale is equal to the size of one degree on the Fahrenheit scale. What is the freezing point of water on the X scale?

A) 492
B) 524
C) 305
D) 440
E) 459

**Ans:**

$$\text{Farenheit: } F = \frac{9}{5}C + 32$$

$$\text{Absolute Zero: } F = \left(\frac{9}{5}\right)(-273.15) + 32 = -459.67\ °F$$

$$\text{Freezing: } F = \left(\frac{9}{5}\right)(0) + 32 = 32\ °F$$

$$X = F + \alpha \longleftarrow \text{constant}$$

$$0 = -459.67 + \alpha \ \Rightarrow\ \alpha = 459.67$$

$$\therefore X = F + 459.67$$

$$\text{Freezing: } X = 32 + 459.67 = 492$$

---

**Q10.**

A 6.00-kg piece of copper is placed in contact with 2.00 kg of water that was initially at 2.00 $^{o}$C. The two objects are placed in an insulated container. If the final equilibrium temperature is 34.3 $^{o}$C, what was the initial temperature of the copper piece? The specific heat of copper is 390 J/kg.K.

A) 150 $^{o}$C
B) 209 $^{o}$C
C) 37.9 $^{o}$C
D) 114 $^{o}$C
E) 129 $^{o}$C

**Ans:**

$$\text{Water: } Q_1 = m_w c_w \Delta T = 2 \times 4190 \times 32.3 = 270674\ \text{J}$$

$$\text{Copper: } Q_2 = m_c . c_c \Delta T = 6 \times 390 \times (34.3 - T)$$

$$= 80262 - 2340\ T$$

$$Q_1 + Q_2 = 0\text{: } 270674 + 80262 - 2340\ T = 0$$

$$\therefore T = 150°C$$

---

**Q11.**

A solid aluminum sphere is initially at 20.0 $^{o}$C, and has a radius of 5.00 cm. What is the radius of the sphere when it is heated to 300 $^{o}$C? The coefficient of linear expansion of aluminum is 23.0 × $10^{-6}$ $(^{o}C)^{-1}$.

A) 5.03 cm
B) 5.10 cm
C) 5.01 cm
D) 5.07 cm
E) 5.12 cm

**Ans:**

$$V_f = V_i(1 + 3\alpha\Delta T)$$

$$\frac{4\pi}{3}{R_f}^3 = \frac{4\pi}{3}{R_i}^3(1 + 3\alpha\Delta T)$$

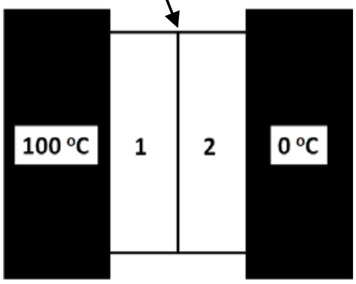
$$R_f = R_i\,.\,[1 + 3\alpha\Delta T]^{\frac{1}{3}} = 5.00 \times [1 + (3 \times 23 \times 10^{-6} \times 280)]^{\frac{1}{3}} = 5.03\text{ cm}$$

---

**Q12.**

Two slabs, of equal area and thickness, are placed side-by-side to form a composite slab between two thermal reservoirs, as shown in **FIGURE 2**. Their thermal conductivities are: $k_1$ = 0.0800 W/m.K and $k_2$ = 0.0100 W/m.K. At steady state, what is the temperature at the junction between the two slabs?

Figure # 2




A) 88.9 $^{o}$C
B) 50.0 $^{o}$C
C) 11.2 $^{o}$C
D) 34.3 $^{o}$C
E) 65.7 $^{o}$C

**Ans:**

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

$$P_2 = \frac{k_2.A.T}{L}$$

Steady State: $P_1 = P_2$

$$\frac{k_1 A(100 - T)}{L} = \frac{k_2 A T}{L}$$

$$100k_1 - k_1T = k_2T$$

$$\therefore T = \frac{100k_1}{k_1 + k_2} = \frac{8}{0.09} = 88.9^{\circ}C$$

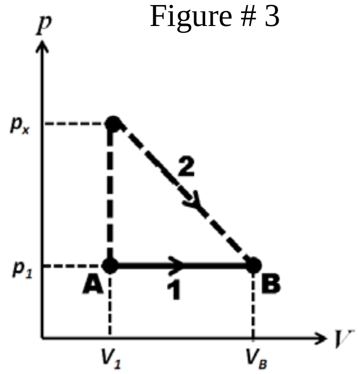
---

**Q13.**

The *p*-*V* diagram in **FIGURE 3** shows two paths along which a sample of an ideal gas can be taken from state ***A*** to state ***B***, where $V_B = 2.0V_1$. Note that path 2 consists of two steps, and that the figure is not to scale. Along path 1, a heat of 5.0 $p_1V_1$ is added to the gas. Along path 2, a heat of 6.0 $p_1V_1$ is added to the gas. What is the ratio $p_x/p_1$?

A) 3.0
B) 1.5
C) 1.2
D) 2.4
E) 2.0

Figure # 3




**Ans:**

$$\Delta E_1 = Q_1 - W_1 = 5P_1V_1 - P_1V_1 = 4P_1V_1$$

$$\Delta E_2 = Q_1 - W_2 = 6P_1V_1 - \left(\frac{1}{2}P_1V_1 + \frac{1}{2}V_1P_x\right)$$

$$= 5.5P_1V_1 - \frac{1}{2}V_1P_x$$

$\Delta E_1 = \Delta E_2$:

$$4P_1V_1 = 5.5\,P_1V_1 - \frac{1}{2}V_1P_x$$

$$\therefore \frac{1}{2}\not{V_1}P_x = 1.5\ P_1\not{V_1} \Rightarrow \frac{P_x}{P_1} = 3.0$$

---

**Q14.**

A quantity of 0.0560 moles of an ideal gas occupies a volume of 1.45 L. If the rms speed of the gas molecules is 185 m/s, what is the pressure of the gas? The molar mass of the gas is $4.00 \times 10^{-3}$ kg/mole.

A) 1.76 kPa
B) 5.31 kPa
C) 3.50 kPa
D) 10.5 kPa
E) 11.7 kPa

**Ans:**

$$\left.\begin{array}{l} v_{rms}{}^2 = \dfrac{3RT}{M} \\ pV = nRT \end{array}\right\} \frac{pV}{v_{rms}{}^2} = \frac{n\not{R}\not{T}}{3\not{R}\not{T}}.M$$

$$\Rightarrow p = \frac{n.M.v_{rms}{}^2}{3V} = \frac{0.056 \times 4 \times 10^{-3} \times (185)^2}{3 \times 1.45 \times 10^{-3}} = 1.76\text{ kPa}$$

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**Q15.**

In an isobaric process, an ideal monatomic gas absorbs 130 J of heat. What is the change in the internal energy of the gas in this process?

A) 78 J
B) 65 J
C) 220 J
D) 95 J
E) 180 J

**Ans:**

$$\left.\begin{array}{r} Q = nc_p\Delta T \\ \Delta E_{int} = nc_v\Delta T \end{array}\right\} \frac{\Delta E_{int}}{Q} = \frac{C_v}{C_p} = \frac{3R/2}{5R/2} = \frac{3}{5} = 0.6$$

$$\therefore \Delta E_{int} = 0.6\ Q = 0.6 \times 130 = 78\ \text{J}$$

---

**Q16.**

Two moles of an ideal diatomic gas, initially at a temperature of – 55.0 $^{o}$C, are compressed adiabatically to one half the initial volume. What is the change in the internal energy of the gas?

A) + 2.90 kJ
B) – 2.90 kJ
C) – 7.30 kJ
D) + 7.30 kJ
E) – 5.30 kJ

**Ans:**

$$T_i V_i^{\gamma-1} = T_f V_f^{\gamma-1}$$

$$\Rightarrow T_f = \left(\frac{V_i}{V_f}\right)^{\gamma-1} . T_i$$

$$= \left(\frac{2V_f}{V_f}\right)^{1.4-1} \times (273.15 - 55) = 287.85\ \text{K}$$

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

$$= 2 \times \frac{5}{2} \times R \times (287.85 - 218.15)$$

$$= +2.90 \times 10^3\ \text{J}$$

$$= +2.90\ \text{kJ}$$

---

**Q17.**

1.00 kg of copper, initially at 20.0 °C, absorbs 5.00 kJ of heat. What is the change of entropy of copper? The specific heat of copper is 390 J/kg.K.

A) 16.7 J/K
B) 19.1 J/K
C) 250 J/K
D) 12.8 J/K
E) zero

**Ans:**

$$Q = m.c.\Delta T \Rightarrow \Delta T = \frac{Q}{m.c} = \frac{5 \times 10^3}{1 \times 390} = 12.82\ ^\circ C$$

$$\Rightarrow T_f = 32.82\ ^\circ C = 305.97\ K$$

$$\Delta S = m.c.\ln\left(\frac{T_f}{T_i}\right) = 1 \times 390 \times \ln\left(\frac{305.97}{293.15}\right) = 16.7\ J/K$$

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**Q18.**

In a large room, 0.250 kg of water is cooled from 85.0 °C to the room temperature of 20.0 °C. The cooling process is isothermal for the air in the room. What is the entropy change of the air?

A) 232 J/K
B) 340 J/K
C) 210 J/K
D) 314 J/K
E) 147 J/K

**Ans:**

$$|Q| = |m.c.\Delta T| = 0.250 \times 4190 \times 65 = 68087.5\ J$$

$$\text{Air: } \Delta S = \frac{Q}{T} = \frac{68087.5}{293.15} = 232\ J/K$$

---

**Q19.**

A Carnot heat engine has an efficiency of 0.590 and performs 250 kJ of work per cycle. If the low temperature reservoir is at 20.0 $^{o}$C, what is the temperature of the hot reservoir?

A) 442 $^{o}$C
B) 48.8 $^{o}$C
C) 224 $^{o}$C
D) 33.9 $^{o}$C
E) 149 $^{o}$C

**Ans:**

$$\varepsilon = \frac{W}{Q_H} \Rightarrow Q_H = \frac{W}{\varepsilon}$$

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

$$\frac{Q_H}{Q_L} = \frac{T_H}{T_L} \Rightarrow T_H = \frac{Q_H}{Q_L}.T_L = \frac{T_L}{1-\varepsilon} = \frac{293.15}{1-0.59} = 715\ K = 442\ ^{\circ}C$$

---

**Q20.**

An ideal refrigerator is placed in a room and operates between 0 $^{o}$C and 25.0 $^{o}$C. How much heat is exhausted into the room when 10.0 kg of liquid water at 0 $^{o}$C is converted to
ice at 0 $^{o}$C?

A) 3.63 MJ
B) 1.09 MJ
C) 5.33 MJ
D) 9.04 MJ
E) 6.23 MJ

**Ans:**

$$Q_L = m.L_F = 10 \times 333 = 3330\ kJ$$

$$K = \frac{T_L}{T_H - T_L} = \frac{273.15}{25} = 10.926$$

$$K = \frac{Q_L}{W} \Rightarrow W = \frac{Q_L}{K} = 304.78\ kJ$$

$$Q_H = W + Q_L = 3.63\ MJ$$