Q1.

A transverse wave traveling on a string is represented by the function y (x, t) = y_m sin[(0.50 m^{-1}) x – (7.00 s^{-1})t] where *x* is in m and *t* is seconds. For which value of the wave amplitude y_m , the maximum transverse speed u_{max} of a particle on the string equals the wave speed *v* on the string.

A) 2.00 m
B) 1.10 m
C) 2.57 m
D) 2.87 m
E) 3.33 m

Ans:

$$|u_{max}| = y_m \omega = v = \frac{\omega}{k}$$

$$y_m = \frac{1}{k} = \frac{1}{0.5} = 2.0 \text{ m}$$

Q2.

A guitar string with 0.550 m length and linear density μ = 1.150 g/m is supposed to have a required fundamental frequency 256 Hz. It currently has a fundamental frequency 248 Hz. What change in tension in the string is required to bring this guitar string into tune with the required frequency?

A) 5.61 N
B) 1.23 N
C) 3.55 N
D) 4.22 N
E) 2.79 N

Ans:

$$f_0 = \frac{v}{2L} = \frac{1}{2L}\sqrt{\frac{\tau}{\mu}};\ f_0^2 = \frac{1}{4L^2\mu}\cdot\tau \Rightarrow \tau = 4L^2\mu\, f_0^2$$

$$\Delta\tau = 4L^2\mu(\,f_2^2 - \,f_1^2) = 4 \times (0.55)^2 \times 1.15 \times 10^{-3} \times (256^2 - 248^2)$$

$$\Delta\tau = 5.61 \text{ N}$$

Q3.

A transverse wave of amplitude y_m and wavelength λ_1 is traveling on a stretched wire with tension τ. The wave carry an average power $P_{1\text{-avg}} = 0.48$ W. Then the wavelength of the wave is doubled ($\lambda_2 = 2\lambda_1$) while keeping the tension τ and amplitude y_m constant. What is the new average power $P_{2\text{-avg}}$ carried by the wave with wavelength λ_2?

A) 0.12 W
B) 0.44 W
C) 0.27 W
D) 0.36 W
E) 0.39 W

Ans:

$$P = \frac{1}{2}\mu v\omega^2 y_m^2 = \frac{1}{2}\mu v v^2 k^2 y_m^2 = \frac{1}{2}\mu v^3 y_m^2 \left(\frac{2\pi}{\lambda}\right)^2$$

$$P = 2\pi^2 \mu v^3 y_m^2 \cdot \frac{1}{\lambda^2}$$

$$\frac{P_2}{P_1} = \left(\frac{\lambda_1}{\lambda_2}\right)^2 \Rightarrow P_2 = P_1 \times \frac{\lambda_1^2}{\lambda_2^2} = 0.48 \times \frac{1}{4} = 0.12 \text{ W}$$

Q4.

A 0.550 m long string fixed at both ends is vibrating in its fundamental mode. The maximum transverse acceleration of a point at the middle of the string is 8.40×10^3 m/s^2 and the maximum transverse velocity is 3.80 m/s. What is the wave speed of the transverse traveling waves on this string?

A) 387 m/s
B) 155 m/s
C) 272 m/s
D) 299 m/s
E) 422 m/s

Ans:

$$\frac{a_{y-max}}{u_{y-max}} = \frac{y_m'\omega^2}{y_m'\omega} = \omega = \frac{8.4 \times 10^3}{3.8} = 2210.5 \text{ rad/s}$$

$$\lambda = 2L = 2 \times 0.55 = 1.1 \text{ m}$$

$$v = \frac{\omega}{k} = \frac{\lambda\omega}{2\pi} = \frac{1.1 \times 2210.5}{2\pi} = 386.99 \text{ m/s}$$

Q5.

One of the harmonic frequencies of a pipe closed at one end is 550 Hz. If the next-highest harmonic frequency of the pipe is 650 Hz, what is the length of the pipe?

A) 1.72 m
B) 2.21 m
C) 2.88 m
D) 3.35 m
E) 4.12 m

Ans:

For a pipe closed at one end

$$\Delta f = \frac{v}{2L} = 650 - 550 = 100$$

$$L = \frac{v}{2\Delta f} = \frac{343}{2 \times 100} = 1.715 \text{ m}$$

Q6.

A train approaches a mountain at a speed of 75.0 km/h. The train driver sounds a whistle that emits a frequency of 420 Hz. What will be the frequency of the echo that the train driver hears reflected from the mountain?

A) 474 Hz
B) 211 Hz
C) 298 Hz
D) 322 Hz
E) 374 Hz

Ans:

$$v_t = \frac{75 \times 1000}{3600} = 20.83 \text{ m/s}$$

$$f'' = f_0\left(\frac{v + v_t}{v - v_t}\right) = 420\left(\frac{343 + 20.83}{343 - 20.83}\right) = 474.3 \text{ Hz}$$

Q7.

A point sound source radiates sound isotropically in all directions in air. At a distance of 5.00 m from the source the sound intensity level is 52.0 dB. If the sound frequency is 587 Hz, what is the pressure amplitude at this distance? (Density of air =1.21 kg/m^3)

A) 1.14×10^{-2} Pa
B) 2.22×10^{-2} Pa
C) 3.13×10^{-2} Pa
D) 4.14×10^{-2} Pa
E) 5.55×10^{-2} Pa

Ans:

$$P_{max} = \sqrt{2\rho v I}; I = I_0 \times 10^{B/10} = 10^{-12} \times 10^{5.7}$$

$$I = 1.585 \times 10^{-7}$$

$$P_{max} = \sqrt{2 \times 1.21 \times 343 \times 1.585 \times 10^{-7}} = 0.01147 = 1.15 \times 10^{-2}\ \text{Pa}$$

Q8.

Two in phase speakers are emitting sound waves of same frequency in a room, as shown in **Figure 1**. For what lowest frequency, the sound from the speakers produce destructive interference at the micro phone located at a distance of 5.00 m in front of one of the speaker?

A) 206 Hz
B) 322 Hz
C) 366 Hz
D) 316 Hz
E) 101 Hz

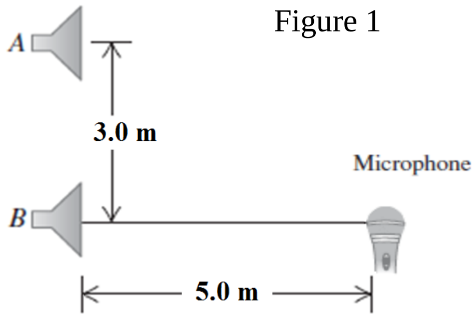


Figure 1

Ans:

$$L_2 = \sqrt{5^2 + 3^2} = 5.83095$$

$$\Delta L = 5.83095 - 5.0 = 0.83095 = \frac{\lambda}{2}$$

$$\lambda = 2\Delta L = 2 \times 0.83095 = 1.6619\ \text{m}$$

$$f = \frac{343}{1.6619} = 206.4\ \text{Hz}$$

Q9.

The density of gasoline at 0.00 °C is 730 kg/m^3. What will be the density of gasoline if its temperature is raised to 30.0 °C. Assume the coefficient of volume expansion of gasoline $\beta = 0.950 \times 10^{-3}$ /°C.

A) 709 kg/m^3
B) 525 kg/m^3
C) 555 kg/m^3
D) 630 kg/m^3
E) 677 kg/m^3

Ans:

$$V_0 = \frac{m}{\rho_0};\ \frac{\Delta V}{V_0} = -\frac{\Delta\rho}{\rho_0} = \beta\Delta T$$

$$\Delta\rho = -\rho_0\beta\Delta T = -730 \times 0.95 \times 10^{-3} \times 30 = -20.80$$

$$\rho_f = \rho_0 - |\Delta\rho| = 730 - 20.80 = 709.2 \text{ kg/m3}$$

Q10.

A metal bar is used to conduct heat. When the temperature at one end of the bar is 100°C and at the other is 20 °C, heat is transferred at a rate of 95 J/s. If the temperature of the hotter end is reduced to 80°C, what will be the rate of heat transfer?

A) 71 J/s
B) 52 J/s
C) 86 J/s
D) 91 J/s
E) 89 J/s

Ans:

$$P = \frac{kA\Delta T}{L};\frac{P_2}{P_1} = \frac{\Delta T_2}{\Delta T_1}$$

$$P_2 = P_1\frac{\Delta T_2}{\Delta T_1} = 95 \times \frac{60}{80} = 71.25\ \text{J/S}$$

Q11.

One kg of ice is mixed with one kg of water at 10.0 °C. When thermal equilibrium is reached, the mixture contains total 2.00 kg of ice at 0.00 °C. Determine the initial temperature of the ice. The specific heat of ice 2092 J/kg °C.

A) – 179 °C
B) – 101 °C
C) – 121 °C
D) – 155 °C
E) – 191 °C

Ans:

$$\Delta Q_{Water} = \Delta Q_{ice}$$

$$m_{Water}(10 \times 4187 + 333 \times 10^3) = m_{ice}\big(2092(-T_{ice} + 0)\big) = m_{ice} \times 2092 \times T_{ice}$$

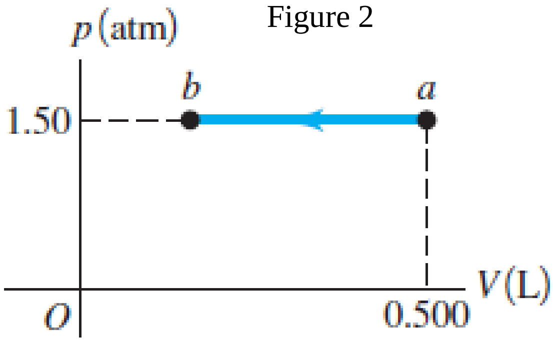
$$T_{ice} = \frac{-(10 \times 4187 + 333 \times 1000)}{2092} = -179.2℃$$

Q12.

Figure 2 shows a pV-diagram for an ideal gas process *a to b* in which its absolute temperature at ***b*** is one-fourth of its absolute temperature at ***a***. How many joules of work was done in this process?

A) –56.8 J
B) –85.6 J
C) –35.5 J
D) –44.6 J
E) –20.5 J

Figure 2



Ans:

$$W = P(V_b - V_a), T_b = \frac{T_a}{4}$$

$$V_b = V_a \times \frac{T_b}{T_a} = \frac{V_a}{4} = \frac{0.5}{4} = 0.125\ L$$

$$W = P(V_b - V_a) = 1.5 \times 1.01 \times 10^5 \times (0.125 - 0.5) \times 10^{-3} = -56.81\ \text{J}$$

Q13.

Suppose the pressure of an ideal monatomic gas is tripled while its volume is halved. What happens to the internal energy of the gas?

A) It increases.
B) It decreases.
C) It stays the same, as the described changes do not affect the internal energy.
D) This depends on the molecular weight of the gas involved, thus this is indeterminate.
E) None of the given answers.

Ans:

$$\Delta E_{in} = nC_vT = C_v \cdot nt = C_v \frac{PV}{R}$$

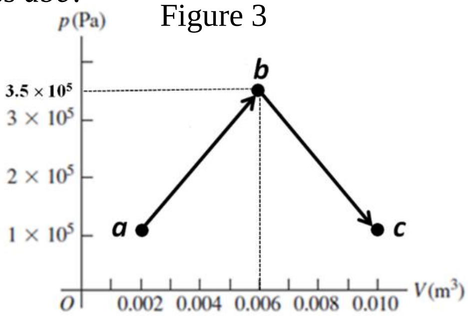
$$\frac{\Delta E_{inf}}{\Delta E_{ini}} = \frac{P_fV_f}{P_iV_i} = 3 \times \frac{1}{2} = \frac{3}{2}$$

$$\Delta E_{inf} = \Delta E_{ini} \times \frac{3}{2}$$

Q14.

One-third of a mole of a monoatomic ideal gas is taken along the path *abc* shown in **Figure 3**. How much heat is transferred in the process *abc*?

Figure 3



A) 3×10^3 J
B) 1×10^3 J
C) 2×10^3 J
D) 5×10^3 J
E) 4×10^3 J

Ans:

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

$$Q_{abc} = \Delta E_{in} + W_{abc} = nC_v(T_c - T_a) + W_{abc}$$

$$\Delta E_{int} = n \times \frac{3}{2} R \times \left(\frac{P_cV_c}{nR} - \frac{P_aV_a}{nR}\right) = \frac{3}{2}(P_cV_c - P_aV_a) = \frac{3}{2} P_a(V_c - V_a)$$

$$\Delta E_{int} = \frac{3}{2} \times 10^5 \times (0.01 - 0.002) = 1200 \text{ J}$$

$$W_{abc} = 10^5 \times (0.01 - 0.02) + 2\left(\frac{0.004 \times 2.5 \times 10^5}{2}\right)$$

$$W_{abc} = 800 + 1000 = 1800 \text{ J}$$

$$Q_{abc} = \Delta E_{in} + W_{abc} = 1200 + 1800 = 3000 \text{ J}$$

Q15.

During a thermal expansion process at constant pressure, 970 J of heat are added to 1.75 mol of an ideal gas to heat it from 10.0 °C to 25.0 °C. The gas does + 223 J of work during the expansion. Calculate γ for the gas.

A) 1.30
B) 1.70
C) 1.40
D) 1.50
E) 1.10

Ans:

$\Delta Q_P = nC_V \Delta T = 970$ J

$\Delta E_{int} = nC_V \Delta T = Q_P - W = 970 - 223 = 747$

$$\gamma = \frac{\Delta Q_P}{\Delta E_{in}} = \frac{C_V}{W} = \frac{970}{747} = 1.30$$

Q16.

How much work is required to compress 5.00 mol of air at 20.0 °C and 1.00 atm to one-fifth of the original volume in an adiabatic process? Assume air behaves as a diatomic ideal gas?

A) 27.5 kJ
B) 21.1 kJ
C) 22.5 kJ
D) 23.3 kJ
E) 25.5 kJ

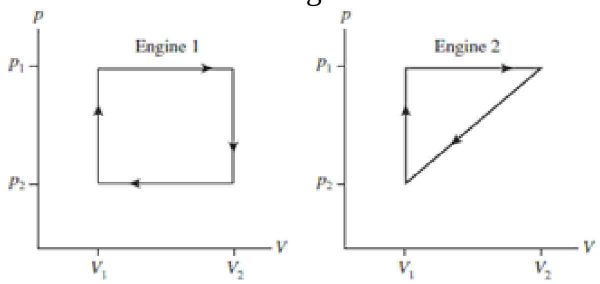
Ans:

A

Q17.

Figure 4 shows the thermodynamic cycles of two heat engines. Determine ratio of the thermal efficiencies ε_1 of engine 1 and ε_2 of engine 2 ($\varepsilon_1 / \varepsilon_2$) if the same amount of heat is added per cycle to each engine.

Figure 4



A) 2.0
B) 0.5
C) 1.0
D) 1.5
E) 1.3

Ans:

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{\text{Area 1}}{\text{Area 2}} = \frac{2}{1} = 2$$

Q18.

One hundred and twenty gram of water is heated to 95.0 °C and then cooled to room temperature at 17.0 °C. The cooling process is essentially isothermal for the air in the room. Calculate the total change in entropy of the water-air system while the water cools down, assuming that all the heat lost by the water goes into the air.

A) +15.5 J/K
B) –15.5 J/K
C) +24.1 J/K
D) –23.2 J/K
E) +19.4 J/K

Ans:

$$\Delta S_{net} = \Delta S_W + \Delta S_{air}$$

$$\Delta S_W = 0.12 \times 4187 \times ln\left(\frac{273 + 17}{273 + 95}\right) = -119.68 \text{ J}$$

$$\Delta S_{air} = \frac{0.12 \times 4187 \times 78}{273 + 17} = +135.139$$

$$\Delta S_{net} = 135.139 - 119.68 = 15.46 \text{ J}$$

Q19.

A heat engine does 10.0 J of work and exhausts 15.0 J of waste heat during each cycle. If the cold-reservoir temperature is 20.0 °C, what is the minimum possible temperature in °C of the hot reservoir?

A) 215 °C
B) 107 °C
C) 127 °C
D) 147 °C
E) 169 °C

Ans:

$$W = 10 \text{ J}, Q_C = 15.05 \text{ J}$$

$$Q_H = W + Q_C = 10 + 15 = 25 \text{ J}$$

$$\varepsilon = \frac{W}{Q_H} = \frac{10}{25} = 0.4$$

T_H cannot be lower than that of a Carnot engine

$$T_H = \frac{T_c}{1 - \varepsilon_c} = \frac{293}{1 - 0.4} = 488.33 = 215.33℃$$

Q20.

Fifty grams of water at 15.0 °C is placed in the freezer compartment of a refrigerator with a coefficient of performance of 4.00. How much work is supplied to the refrigerator to convert 50.0 g water at 15.0 °C into ice at 0.00 °C.?

A) 4.95×10^3 J
B) 1.33×10^3 J
C) 2.45×10^3 J
D) 2.88×10^3 J
E) 3.58×10^3 J

Ans:

$$W = \frac{Q_L}{K}; Q_L = m_\omega \times (C \times \Delta T + L_F) = 0.05 \times (4187 \times 15 + 333 \times 10^3)$$

$$Q_L = 19792.5 \text{ J}$$

$$W = \frac{19792.5}{4} = 4948.0 \text{ J} = 4.95 \times 10^3 \text{ J}$$