Q1. A wave on a stretched string is described by the displacement wave $y = 0.400 \sin(300t - 15.0x)$, where x and y are in meters and t is in seconds. What is the phase difference between two points on the string 21.0 cm apart?

A) 3.15 rad
B) 2.45 rad
C) 0.785 rad
D) 5.34 rad
E) 4.70 rad

Solution:

$$\Delta\emptyset = \frac{2\pi}{\lambda}\Delta X \quad , \quad \lambda = \frac{2\pi}{k} = \frac{2\pi}{15}$$

$$\Delta\emptyset = \frac{2\pi}{2\pi} \times 15 \times 0.21 = \boxed{3.15 \text{ rad}}$$

Sec# Wave - I - Wavelength and Frequency

Q2. A rope of length 4.24 m and mass 1.27 kg is under a tension of 475 N. It oscillates with a frequency of 11.2 Hz. If the oscillation amplitude is 6.32 cm, how much power is required to keep the rope oscillating?

A) 118 W
B) 216 W
C) 10.5 W
D) 90.2 W
E) 289 W

Solution:

$$\mu = \frac{mass}{leng\,ht} = 0.3 \text{ kg/m}$$

$$w = 2\pi f = 70.4 \text{ rad/s}$$

$$V = \sqrt{\frac{\tau}{\mu}} \qquad v = 39.8 \text{ m/s}$$

$$P = \frac{1}{2}\mu v w^2 {y_m}^2 \Rightarrow P = \frac{1}{2} \times 0.3 \times 39.8 \times (70.4)^2 \times (0.0632)^2 = \boxed{118 \text{ W}}$$

Sec# Wave - I - Energy and Power of a Traveling String Wave

Q3. Two sinusoidal waves travel simultaneously through the same medium. The first wave is described by $y_1(x,t) = y_m \cos(kx-\omega t)$ and the second wave by $y_2(x,t) = y_m \cos(kx-\omega t + \varphi)$. If the amplitude of the resulting superposition is $y_m/2$, what is the value of φ in radian?

A) 2.6
B) 1.9

C) 3.5
D) 9.8
E) zero

Solution:

$$\frac{y_m}{2} = 2\,y_m \,\mathrm{COS}(\frac{\phi}{2})$$

$$\Rightarrow \mathrm{COS}(\frac{\phi}{2}) = \frac{1}{4} \qquad \emptyset = 2 \times \cos^{-1}(\frac{1}{4}) = \boxed{2.6\text{ rad}}$$

Sec# Wave - I - Interference of Waves

Q4. A string, fixed at both ends, has a fundamental frequency f_a = 248 Hz. The tension τ in the same string is changed so that the new fundamental frequency is f_b = 496 Hz. What is the value of the ratio τ_b/τ_a?

A) 4.00
B) 2.00
C) 0.500
D) 1.00
E) 3.00

Solution:

$$f_a = \frac{nv_a}{2L}$$

$$f_b = \frac{nv_b}{2L}$$

$$\frac{f_b}{f_a} = \frac{v_b}{v_a} = \sqrt{\frac{\tau_b}{\tau_a}} \qquad \Rightarrow \frac{\tau_b}{\tau_a} = (\frac{f_b}{f_a})^2 = \boxed{4}$$

Sec# Wave - I - Standing Waves

Q5. The sound from a single source can reach point O by two different paths. One path has a length 20.0 m and the second path has a length 21.0 m. The sound destructively interferes at point O. What is the minimum frequency of the source if the speed of sound is 340 m/s?

A) 170 Hz
B) 100 Hz
C) 520 Hz
D) 680 Hz
E) 340 Hz

Solution:

$$\Delta L = \frac{\lambda}{2} = \frac{\mathrm{v}}{2f}$$

$\Delta L = 21 - 20 = 1\ m$

$f = \frac{V}{2\Delta L} = \frac{340}{2} = 170\ Hz$

Sec# Wave - II - Interference

Q6. Which one of the following statements is **TRUE**?

A) If two sound waves have the same intensity level (in decibels), they must have the same intensity.
B) If two different sound waves have the same displacement amplitude, then they must have the same intensity level (in decibels).
C) If the intensity level (in decibels) of sound *A* is twice the intensity level of sound *B*, then the intensity of *A* is twice the intensity of *B*.
D) If two different sound waves have the same displacement amplitude, then they must have the same intensity.
E) If the intensity of sound *A* is twice the intensity of sound *B*, then the intensity level (in decibels) of *A* is twice the intensity level of *B*.

Ans: A)

Sec# Wave - II - Intensity and Sound Level

Q7. A pipe, open at both ends, resonates in its second harmonic with a frequency of 1200 Hz. In this situation, the distance between two consecutive antinodes, in cm, is (Take the speed of sound = 343 m/s)

A) 14.3 cm
B) 17.7 cm
C) 12.1 cm
D) 57.2 cm
E) 28.6 cm

Solution:

$\Delta X = \frac{\lambda}{2} = \frac{V}{2f} = \frac{V}{2f} = \frac{343}{2 \times 1200} = 0.143\text{m} = \boxed{14.3\text{ cm}}$

Sec# Wave - II - Source of Musical Sound

Q8. As you stand by the side of the road, a car approaches you at a constant speed, sounding its horn, and you hear a frequency of 80.0 Hz. After the car passes you, you hear a frequency of 60.0 Hz. What is the speed of the car? Assume that the speed of sound in air is 343 m/s.

A) 49.0 m/s
B) 64.0 m/s
C) 16.0 m/s
D) 36.0 m/s

E) 25.0 m/s

Solution:

f^{1} = f $\frac{v+v_c}{v}$ f^{11} = f $\frac{v-v_c}{v}$

$\frac{f^{1}}{f^{11}} = \frac{v+v_c}{v-v_c}$

$\frac{80}{60} = \frac{v+v_c}{v-v_c}$

8V-8v_c = 6V + 6 v_c $\Rightarrow$ v_c = $\frac{2}{14}$ v = $\frac{2 \times 343}{14}$ = 49 m/s

Sec# Wave - II - The Doppler Effect

Q9. One end of a cylindrical rod of length 50.0 cm and area of cross-section 11.5 cm^2 is placed in a steam bath at 100 ^oC whereas the other end is inserted into an ice bath at 0 ^oC. If 500 g of ice melts in 30.0 min, what is the rod made up of:

A) Copper: (k = 402 W/m.K)
B) Wood: (k =0.100 W/m.K)
C) Steel: (k = 14.0 W/m.K)
D) Silver: (k = 428 W/m.K)
E) Plastic: (k =0.0500 W/m.K)

Solution:

$\frac{Q}{t} = \frac{kA\,\Delta T}{L} = \frac{m\,L_f}{t}$

k = $\frac{mL_f L}{A\Delta Tt} = \frac{0.5 \times 3.33 \times 10^5 \times 0.5}{11.5 \times 10^{-4} \times 100 \times 1800}$ = $402\,\frac{w}{mK}$

Sec# Temerature, Heat, and the First Law of Thermodynamics - Heat Transfer Mechanisms

---

Q10. 1.00 kg of steam at 100 ^oC is mixed with 1.00 Kg of ice at 0 ^oC. Assuming the system is isolated, the final temperature of the mixture is:

A) 100 ^oC
B) 50.0 ^oC
C) zero ^oC
D) 279 ^oC
E) 25.0 ^oC

Solution:

Ice will gain heat Q = ml_f+mc$\Delta t + ml_v$
to become steam at 100°C = 1[3.33$\times 10^5 + 2220 \times 100 + 2.256 \times 10^6$]

$= 2.81\times 10^6 J$

Steam will lose heat to become water at $100°C$ $Q = ml_v = 1 \times 2.256 \times 10^6 J$ (not enough energy to convert ice into steam at $100°C$)

but enough energy to turn ice into water at $100°C$ $\Rightarrow$ So the mixture will be water at $100°C$

Sec# Temperature, Heat, and the First Law of Thermodynamics - The Absorption of Heat by Solids and Liquids

---

Q11. When the average temperature of the earth increased by 1.00 C^o, commonly known as global warming, the volume of the ocean due to expansion will be increased by: (Coefficient of volume expansion for water = 2.07 x 10^{-4}/ C^o)

A) 0.021 %
B) 0.200 %
C) 1.00 %
D) 0.400 %
E) 4.00 %

Solution:

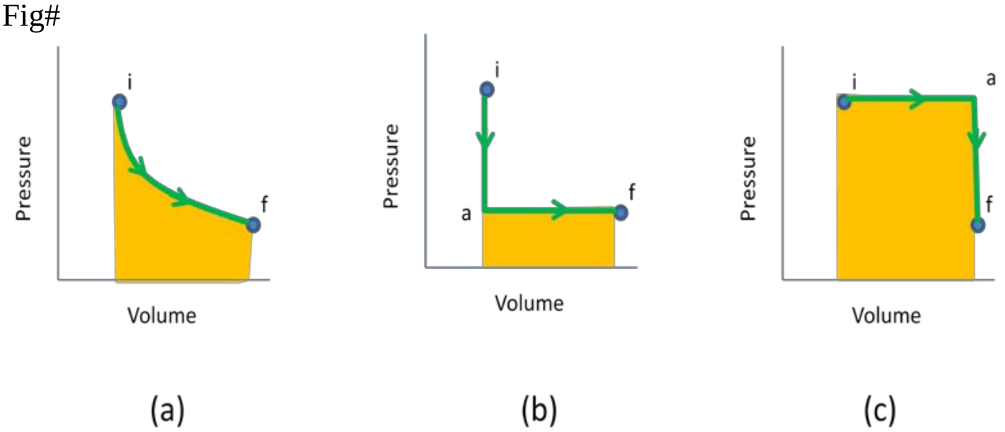
$$\frac{\Delta V}{V} = \frac{\not{V}\,\beta\,\Delta T}{\not{V}} = \beta\Delta T = 2.07 \times 10^{-4} \times 1 = 2.07 \times 10^{-2}\% = \boxed{0.021}$$

Sec# Temperature, Heat, and the First Law of Thermodynamics - Thermal Expansion

---

Q12. Which of the following statements is **FALSE** regarding the processes connecting the same points i and f shown in the three diagrams in Figure 1?

Fig#



A) Change in internal energy is different in all three processes
B) Work is different in all three processes
C) Heat energy transfer is different in all three processes
D) The first law of thermodynamics can be applied to the three processes
E) The work is positive in all three processes

Solution: A)

Sec# Temperature, Heat, and the First Law of Thermodynamics - Some Special Cases of the First Law of Thermodynamics

---

Q13. A monatomic ideal gas at a pressure 1.01 x 10^5 Pa expands adiabatically to 3 times its initial volume. The new pressure is:

A) 1.62 x 10^4 Pa
B) 3.03 x 10^4 Pa
C) 1.01 x 10^6 Pa
D) 3.03 x 10^6 Pa
E) 1.62 x 10^6 Pa

Solution:

$P_i \, v_i{}^{\gamma-1} = P_f \, v_f{}^{\gamma-1}$ $\gamma = \frac{c_p}{c_v} = \frac{5}{3} = 1.67$

$1.01\times\ 10^5\ (\frac{1}{3})^{1.67} = P_f = \boxed{1.62\times10^4\ P_a}$

Sec# The kinetic Theory of Gases - The Adiabatic Expansion of an Ideal Gas

---

Q14. Two mole of hydrogen gas at 27.00 ^{o}C are compressed through isobaric process to half of the initial volume. If we assume hydrogen to be an ideal gas, the final RMS speed of the hydrogen molecules is: (Molar mass of Hydrogen = 2.020 grams)

A) 1361 m/s
B) 1920 m/s
C) 1851 m/s
D) 149.0 m/s
E) 1.850 x 10^6 m/s

Solution:

$\frac{v_i}{T_i} = \frac{V_f}{T_f}$ $T_f = T_i \frac{v_f}{v_i} = 150\text{K}$

$V_{rms} = \sqrt{\frac{3RT}{M}}$

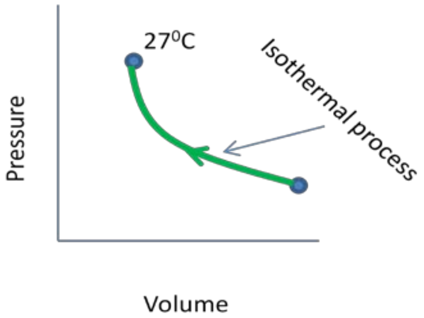
$V_{rms} = \sqrt{\frac{3\times8.31\times150}{2.02\times10^{-3}}} = 1361$ m/s

Sec# The kinetic Theory of Gases - Pressure, Temperature and RMS Speed

---

Q15. In the isothermal process shown in Figure 2 **the work done on** 5.000 mole of monatomic ideal gas is 2275 J. Find the ratio of final to initial volumes.

Fig#



A) 0.8332
B) 2.012
C) 7.240
D) 1.036
E) 0.5100

Solution:

$$W = n\,RT\,ln(\frac{v_f}{v_i})$$

$$\frac{v_f}{v_i} = e^{\frac{w}{nRT}} = e^{-\frac{2275}{5\times 8.31\times 300}} = 0.8332$$

Sec# The kinetic Theory of Gases - Ideal Gases

Q16. The internal Energy of a certain volume of gas enclosed in a container **DOES NOT** depend on:

A) The shape of the container
B) The molecular mass of the gas
C) The temperature of the gas
D) The kinetic energy of the molecules of the gas
E) The number of atoms in a molecule of the gas

Solution: A) and B)

Sec# The kinetic Theory of Gases - Ideal Gases

Q17. A 200 g of aluminum at 100 ^oC is mixed with 50.0 g of water at 20.0 ^oC, with the mixture thermally isolated. The aluminum-water system comes to equilibrium at 57.0 ^oC. What is the entropy change of the aluminum-water system? (specific heat of aluminum = 900 J/kg K)

A) + 2.86 J/K
B) – 2.86 J/K
C) + 4.52 J/K
D) – 4.52 J/K
E) – 3.60 J/K

Solution:

ΔS_{AL} = m C_{AL} $ln(\frac{T_f}{T_i})$ = 0.2 × 900 × ln ($\frac{330}{373}$) = -22.05 $\frac{J}{K}$

ΔS_{W} = m C_{W} $ln(\frac{T_f}{T_i})$ = 0.05 × 419 × ln ($\frac{330}{293}$) = 24.91 $\frac{J}{K}$

ΔS_{Total} = 2.86 $\frac{J}{K}$

Sec# Entropy and the Second Law of Thermodynamics - Change in Entropy

---

Q18. A certain heat engine extracts 500 calories from a water bath at 27.0 ^{o}C and transfers 400 calories to a reservoir at a lower temperature. The efficiency of this engine is:

A) 20.0 %
B) 10.0 %
C) 50.0 %
D) 65.0 %
E) 80.0 %

Solution:

E = 1 - $\frac{Q_L}{Q_H}$ = 1 - $\frac{400}{500}$ = 0.2 = 20%

Sec# Entropy and the Second Law of Thermodynamics - Entropy in the Real World: Engines

---

Q19. What is the entropy change for 5.00 mole of an ideal monatomic gas undergoing a reversible increase in temperature from 100 ^{o}C to 150 ^{o}C at constant volume?

A) + 7.84 J/K
B) + 1.20 J/K
C) + 12.5 J/K
D) + 0.500 J/K
E) – 1.00 J/K

Solution:

$\Delta S = n\, c_v\, ln\,(\frac{T_f}{T_i}) = 5 \times \frac{3}{2} \times 831\, ln\,(\frac{423}{373})$

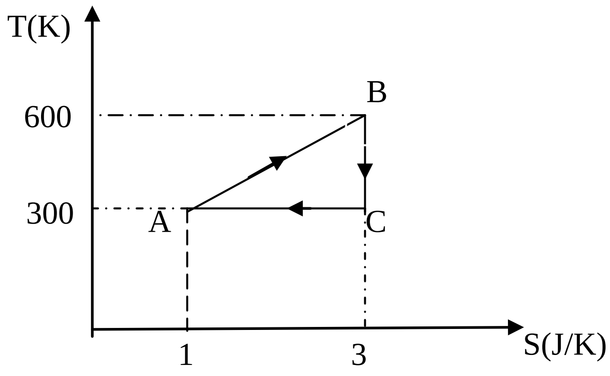
= 7.84 J/K

Sec# Entropy and the Second Law of Thermodynamics - Change in Entropy

---

Q20. Figure 3 shows T versus S diagram of 4.00 moles of an ideal monatomic gas undergoing a reversible cyclic process. How much energy is absorbed as heat by the gas during the process from A to B?

Fig#



A) 900 J
B) 150 J
C) 750 J
D) 200 J
E) 250 J

Solution:

Q = $\int T ds$ = area under the curve

$= \frac{1}{2} 300 \times 2 + 300 \times 2 = 300 + 600 = \boxed{900\ \text{J}}$

Sec# Entropy and the Second Law of Thermodynamics - Change in Entropy