

This test is closed book except for the notes provided, Show enough work for FULL credit. Attach extra white paper as needed - just indicate such. Each problem is 5 points unless otherwise noted. Multiple choice questions require a brief justification.

Ch 12 -- Sound

1 Seven seconds after a brilliant flash of lightning, thunder shakes the house. Approximately how far was the lightning strike from the house?

- A) about two kilometers away
- B) much farther away than two kilometers
- C) about one kilometer away
- D) much closer than one kilometer
- E) It is impossible to say.

$$\{v = 343 \text{ m/s}\} * 7 \text{ s} = 2100 + 280 + 21 = 2400 \text{ m}$$

5

2 The lowest tone to resonate in pipe of length L that is open at both ends is 200 Hz. Which one of the following frequencies will *not* resonate in the same pipe?

- A) 800 Hz
- B) 200 Hz
- C) 600 Hz
- D) 900 Hz
- E) 400 Hz

↑ not a multiple of 200

5

3 Consider a pipe of length L that is open at one end and closed at the other end. What are the wavelengths of the three lowest-pitch tones produced by this pipe?

- A) $2L, L, L/2$
- B) $4L, 2L, L$
- C) $4L, 4L/3, 4L/5$
- D) $2L, L, 2L/3$

$$\begin{matrix} \div 3 \\ \div 5 \end{matrix}$$



$n = 1, 3, 5, \dots$

5

4 Two strings both vibrate at exactly 819 Hz. The tension in one of them is then increased slightly. As a result, six beats per second are heard when both strings vibrate. What is the new frequency of the string that was tightened?

- A) 825 Hz
- B) 822 Hz
- C) 813 Hz
- D) 816 Hz

$$\Delta \omega = \omega_1 - \omega_2$$

$$\begin{array}{r} 819 \\ 6 \\ \hline 825 \end{array}$$

5

5 In many cartoon shows, a character runs off a cliff, realizes his predicament, and lets out a scream. He continues to scream as he falls. If the physical situation is portrayed correctly, from the vantage point of an observer at the bottom of the cliff, the pitch of the scream as he falls should be

- A) higher than the original pitch and increasing as he falls.
- B) lower than the original pitch and decreasing as he falls.
- C) lower than the original pitch and constant.
- D) higher than the original pitch and constant.
- E) It is impossible to predict.

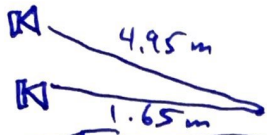
- speed increases
- coming towards you

5

6 A person stands between two speakers driven by the same source. Each speaker produces a tone with a frequency of 200 Hz on a day when the speed of sound is 330 m/s. The person is 1.65 m from one speaker and 4.95 m from the other. What type of interference does the person perceive?

- A) constructive
 B) destructive
 C) both constructive and destructive
 D) neither constructive nor destructive

5



$$\Delta = 4.95 - 1.65 = 3.30 \text{ m}$$

$$\lambda = \frac{v \text{ m/s}}{f \text{ c/s}} = \frac{330}{200} = 1.65$$

*2 = 3.43 m ← roughly two wavelength difference
 *1.5 = 2.625
 *1 = 1.75
 ⇒ constructive

7) By how many decibels does the intensity level of a sound decrease when you triple your distance from a source of sound?

5

• assume spherical spreading

$$I_1 \propto \frac{1}{r_1^2}$$

$$I_1 r_1^2 = I_2 r_2^2$$

$$\frac{I_2}{I_1} = \left(\frac{r_1}{r_2}\right)^2$$

$$r_2 = 3r_1$$

$$\frac{I_2}{I_1} = \left(\frac{r_1}{3r_1}\right)^2$$

$$\frac{I_2}{I_1} = \frac{1}{9}$$

$$\Delta \beta = 10 \log \left(\frac{I_2}{I_1}\right)$$

$$= 10 \log \left(\frac{1}{9}\right)$$

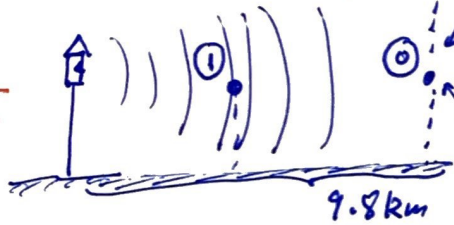
$$= 10 \log (0.111)$$

$$= 10 (-0.954)$$

$$\Delta \beta = -9.54 \text{ dB (decreases)}$$

8) A certain factory whistle can be heard up to a distance of 9.8 km. Assuming that the acoustic output of the whistle is uniform in all directions, ($1/r^2$ decay) at what distance from the factory is the intensity level of the whistle sound equal to 25 dB? The threshold of human hearing is $1.0 \times 10^{-12} \text{ W/m}^2$.

5



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

$$\beta = 10 \log \left(\left(\frac{r_0}{r_1}\right)^2\right)$$

$$25 = 10 \log \left[\left(\frac{9.8}{r_1}\right)^2\right]$$

$$25 = 20 \log \left(\frac{9.8}{r_1}\right)$$

$$10^{25/20} = 9.8/r_1$$

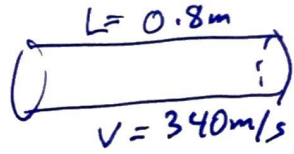
$$r_1 = \frac{9.8}{10^{25/20}}$$

$$r_1 = 0.55 \text{ km}$$

$$= 550 \text{ m}$$

9) An organ pipe open at both ends has a length of 0.80 m. If the velocity of sound in air is 340 m/s, what is the frequency of the second harmonic of this pipe?

5



$$\lambda_n = \frac{2L}{n}$$

$$\lambda_2 = \frac{2(0.8 \text{ m})}{2}$$

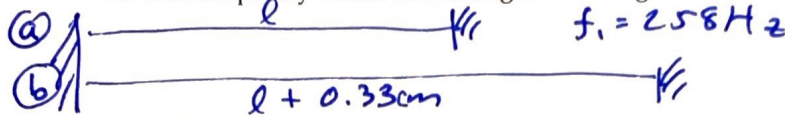
$$\lambda_2 = 0.8 \text{ m}$$

$$f_2 = \frac{v \text{ m/s}}{\lambda \text{ m/c}}$$

$$= \frac{340 \text{ m/s}}{0.8 \text{ m/c}} = 425 \text{ c/m} = 425 \text{ Hz}$$

20

- 1 Two taut strings of identical mass per unit length are stretched with the same tension with their ends fixed, but one string is 0.330 cm longer than the other. The fundamental frequency of the shorter string is 258 Hz. What is the beat frequency when each string is vibrating at its fundamental frequency?



$$\Delta f = ?$$

5
ec.

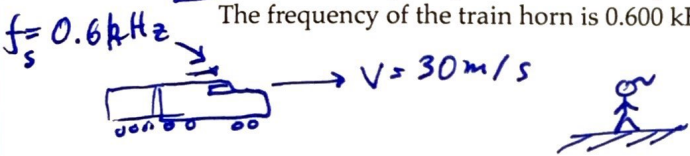
(i) $v = \sqrt{\frac{F_T}{\mu}}$
 $v_a = v_b$
 $f_a = v / \lambda_a$

$$\begin{cases} \lambda_a = v / f_a \\ \lambda_b = v / f_b \\ 2l = v / f_a \\ 2(l + 0.33\text{cm}) = v / f_b \end{cases}$$

$$f_a - f_b = \frac{v}{2l} - \frac{v}{2l + 0.66\text{cm}}$$

Sorry, we need the reference length not provided.

- 11 What is the frequency does a stationary observer hear when a train approaches her with a speed of 30 m/s. The frequency of the train horn is 0.600 kHz and the speed of sound is 340 m/s.



5 $f' = f_s \left(\frac{v_s \pm v_{obs}}{v_s \mp v_{source}} \right) = 600\text{Hz} \left(\frac{340 + 0}{340 - 30} \right) = 600 \left(\frac{340}{310} \right) = \underline{\underline{658.1\text{ Hz}}}$

Ch 13 -- Temperature and Kinetic Theory

- 12 Which two temperature changes are equivalent?

- A) 1 K = 1 F°
 C) 1 F° = 1 C°

- B) 1 C° = 1 K
 D) none of the above

5

- 13 The coefficient of linear expansion for aluminum is $1.8 \times 10^{-6} \text{ K}^{-1}$. What is its coefficient of volume expansion?

- A) $9.0 \times 10^{-6} \text{ K}^{-1}$
 B) $0.60 \times 10^{-6} \text{ K}^{-1}$
 C) $5.4 \times 10^{-6} \text{ K}^{-1}$
 D) $5.8 \times 10^{-18} \text{ K}^{-1}$
 E) $3.6 \times 10^{-6} \text{ K}^{-1}$

$$\begin{aligned} \beta &= 3\alpha \\ &= 3(1.8 \times 10^{-6} / \text{K}) \\ &= 5.4 \times 10^{-6} / \text{K} \end{aligned}$$

5

15)

14) Two metal spheres are made of the same material and have the same diameter, but one is solid and the other is hollow. If their temperature is increased by the same amount,

- A) the hollow sphere becomes bigger than the solid one.
 - B) the two spheres remain of equal size.
 - C) the solid sphere becomes bigger than the hollow one.
 - D) the solid sphere becomes less dense and the hollow one denser.
 - E) the solid sphere becomes denser and the hollow one less dense.
- } Both becomes less dense

5

15) Two containers of equal volume each hold samples of the same ideal gas. Container A has twice as many molecules as container B. If the gas pressure is the same in the two containers, the correct statement regarding the absolute temperatures T_A and T_B in containers A and B, respectively, is

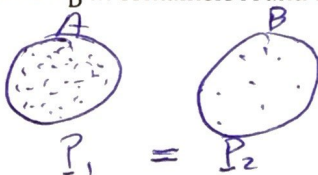
A) $T_A = \frac{1}{4} T_B$.

B) $T_A = 2 T_B$.

C) $T_A = \frac{1}{2} T_B$.

D) $T_A = T_B$.

E) $T_A = \frac{1}{\sqrt{2}} T_B$.



$$\frac{P_1 V_1 = n_1 R T_1}{P_2 V_2 = \frac{n_1}{2} R T_2}$$

$$1 = 2 \frac{T_1}{T_2}$$

$$\frac{T_B}{2} = T_A$$

5

16) The root-mean-square speed of the molecules of an ideal gas is v . The gas is now slowly compressed to one-half its original volume with no change in temperature. What is the root-mean-square speed of the molecules now?

A) v

B) $4v$

C) $v/\sqrt{2}$

D) $2v$

E) $v/2$

$$v_{rms} = \sqrt{\frac{3kT}{m}}$$

Temp $\propto v^2$

So same temperature means same rms velocity

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17) A fixed container holds oxygen and helium gases at the same temperature. Which of the following statements are correct? (There could be more than one correct choice.)

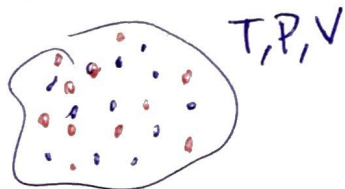
A) The helium molecules have the same average kinetic as the oxygen molecules.

B) The oxygen molecules have the greater average kinetic energy.

C) The oxygen molecules have the greater speed.

D) The helium molecules have the greater average kinetic energy.

E) The helium molecules have the greater speed. *because it has less mass*



• = O_2

• = He

$$v_{rms} = \sqrt{\frac{3kT}{m}}$$

5

18) The coefficient of linear expansion of copper is $17 \times 10^{-6} \text{ K}^{-1}$ and that of steel is $12 \times 10^{-6} \text{ K}^{-1}$. At 12°C a steel rod has a diameter of 2.540 cm and a copper pipe has a diameter of 2.536 cm. If they are heated together to a higher temperature, which one of the following quantities is closest to the common temperature at which the steel rod will fit snugly in the copper pipe?

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$12^\circ\text{C} \left\{ \begin{array}{l} D_{\text{steel}} = \underline{2.540 \text{ cm}}, \alpha_s = 12 \times 10^{-6} / \text{K} \leftarrow \text{rod} \\ D_{\text{cu}} = \underline{2.536 \text{ cm}}, \alpha_c = 17 \times 10^{-6} / \text{K} \leftarrow \text{pipe} \end{array} \right.$
(Steel) Copper
↑ expands faster

$\Delta l = \alpha l_0 \Delta T$

let fit occur at D_f

- $2.540 \text{ cm} + \Delta d_s = D_f$
- $2.536 \text{ cm} + \Delta d_c = D_f$

$\Rightarrow \left\{ \begin{array}{l} 2.540 \text{ cm} + \alpha_s 2.540 \Delta T = \\ 2.536 \text{ cm} + \alpha_c 2.536 \Delta T \end{array} \right.$

$2.536 - 2.540 = (\alpha_s 2.540 - \alpha_c 2.536) \Delta T$
 $\Rightarrow \Delta T = \frac{2.536 - 2.540}{(12 \times 10^{-6})(2.540) - (17 \times 10^{-6})(2.536)}$
 $= \frac{-0.004}{-12.53 \times 10^{-6}} = 319.23$
 $T_{\text{fit}} = 319.23 + 12 = \boxed{331^\circ\text{C}}$

19) A weather balloon containing 2.0 m^3 of hydrogen gas rises from a location at which the temperature is 22°C and the pressure is 101 kPa to a location where the temperature is -39°C and the pressure is 20 kPa. If the balloon is free to expand so that the pressure of the gas inside is equal to the ambient pressure, what is the new volume of the balloon?

5

$PV = nRT \Rightarrow \frac{P_0 V_0}{T_0} = \frac{P_{\text{new}} V_{\text{new}}}{T_{\text{new}}}$

$V_{\text{new}} \leftarrow -39^\circ\text{C}, 20 \text{ kPa}$

$V_{\text{new}} = \frac{P_0 V_0 T_{\text{new}}}{T_0 P_{\text{new}}}$

$= \frac{(101)(2 \text{ m}^3)(273 - 39)}{(273 + 22)(20)}$

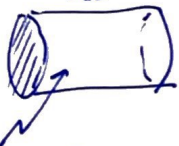
$V_0 \leftarrow 22^\circ\text{C}, 101 \text{ kPa}$

$V_n = \frac{10 \cdot 234}{295} = \boxed{7.9 \text{ m}^3}$

20) A 0.50 m^3 gas tank holds 3.0 moles of ideal diatomic nitrogen gas at a temperature of 350 K. The atomic mass of nitrogen is 14.0 g/mol. What is the rms speed of the molecules? (The Boltzmann constant is $1.38 \times 10^{-23} \text{ J/K}$, $N_A = 6.022 \times 10^{23} \text{ molecules/mol}$.)

5

$N_2 = 28 \text{ g/mol}$



0.5 m^3
 $n = 3 \text{ mol}$
 350 K

mass:
 $m = \frac{0.028 \text{ kg/mol}}{6.022 \times 10^{23} \text{ molec/mol}}$
 $= \underline{4.65 \times 10^{-26} \text{ kg/molec}}$

$v = \sqrt{\frac{3kT}{m}}$

$v = \sqrt{\frac{3(1.38 \times 10^{-23} \text{ J/K})(350 \text{ K})}{4.65 \times 10^{-26} \text{ kg}}}$

$= \boxed{558 \text{ m/s}}$

Ch 12 Sound

Speed of sound in air: $v \approx (331 + 0.60T) \text{ m/s}$, $v = 343 \frac{\text{m}}{\text{s}}$ @ $T = 20^\circ\text{C}$ ↙ temperature

Sound level: $\beta \text{ (in dB)} = 10 \log \left(\frac{I}{I_0} \right)$, $I_0 = 10^{-12} \text{ W/m}^2$ ↙ threshold

$$\beta_2 - \beta_1 = 10 \log \left(\frac{I_2}{I_1} \right)$$

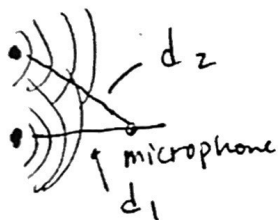
Molecule motion: Amplitude = $\frac{1}{\pi f} \sqrt{\frac{I}{2\rho v}}$

{ Piano/Harp
{ Violin
{ Guitar Strings \rightarrow $f_n = n f_1 = n \frac{v}{2L}$, $n = 1, 2, 3, \dots$, $v = \sqrt{\frac{F_T}{\mu}}$ String
↓

also \rightarrow $\lambda_n = \frac{2L}{n}$
 • open tubes \rightarrow $f_n = v/\lambda_n$, $\lambda_1 = v/f_1$

• closed tube \rightarrow $f_n = n f_1 = n \frac{v}{4L}$, $f_1 = \frac{v}{4L}$, $\lambda_1 = 4L$, $\lambda = \frac{v}{f_n}$
 $n = 1, 3, 5, \dots$

Interference:



Constructive: $\Delta d = d_2 - d_1 = n\lambda$
 Destructive: $\Delta d = \frac{(2n-1)\lambda}{2}$

Beats: $f_{\text{Beat}} = f_1 - f_2$

Doppler: $f' = (f) \left(\frac{v_{\text{sound}} \pm v_{\text{observer}}}{v_{\text{sound}} \mp v_{\text{source}}} \right)$
↑ observer ↑ source

pick signs so that
 $f' > f$ if approaching
 $f' < f$ if receding



Chapter 13 Formulas

$N_A = 6.02 \times 10^{23}$ items/mol

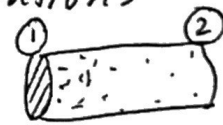
• Temperature $T(K) = T(^{\circ}C) + 273.15$
 $\Delta T(^{\circ}C) = \Delta T(K) = \frac{9}{5} \Delta T(^{\circ}F)$

• Thermal Expansion $\Delta l = \alpha l_0 \Delta T$ (linear)
 $\Delta V = \beta V_0 \Delta T$ (3-D) $\beta = 3\alpha$
volume

• Thermal Stress $F/A = \alpha E \Delta T$

• Gas Law : $PV = nRT$, $R = 8.314 \text{ J/mol}\cdot\text{K}$
 $PV = NkT$, $k = \frac{R}{N_A} = 1.38 \times 10^{-23} \text{ J/K}$
 $\frac{PV}{T} = \text{const}$ if mass remains constant

• Kinetic Thy : $\overline{KE} = \frac{1}{2} m \overline{v^2} = \frac{3}{2} kT$

• Diffusion : $J = DA \left(\frac{C_1 - C_2}{\Delta x} \right)$ 
concentrations
Diffusion Constant

• Pressure in Ideal Gas : $F_{\text{Area}} = \frac{m}{l} N \frac{\overline{v^2}}{3}$
 $P = \frac{1}{3} \frac{Nm \overline{v^2}}{V}$

• Speed of molecules or atoms in a gas @ Temp T:

$v_{\text{rms}} = \sqrt{\frac{3kT}{m}}$

$P = \rho gh$