11) Race car tires operate at high temperatures. At $T_{cool} = 20^oC$ the tires are filled with $P_{cool} = 25.9\ PSI$, and put on the race car. After 5 laps, the tires reach $T_{hot} = 66.5^oC$. What is the pressure in the tires (assume the volume of the tires is constant)?

$$PV = nRT \Rightarrow \frac{P_1}{P_2} = \frac{T_1}{T_2} \Rightarrow P_2 = P_1 \frac{T_2}{T_1}$$

a. $P_{hot} = 22.4\ PSI$
b. $P_{hot} = 86.1\ PSI$
(c.) $P_{hot} = 30\ PSI$

$$P_2 = 25.9\ PSI \times \frac{66.5 + 273}{20 + 273}$$

$$= 30.0\ PSI$$

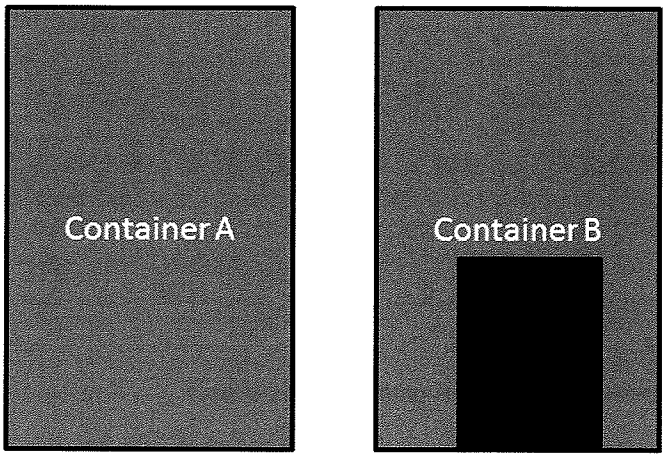
12) A liquid has a density at $289\ K$ of $955\ kg/m^3$. Its (volume) thermal expansion coefficient is $1.05x10^{-3}/K$. $= \gamma$ What is its density at $316\ K$?

$$\frac{\Delta V}{V} = \gamma \Delta T = 1.05 \times 10^{-3}\ K^{-1} \times (316 - 289)\ K = 0.0284$$

a. $983\ kg/m^3$
b. $1050\ kg/m^3$
(c.) $929\ kg/m^3$
d. $1020\ kg/m^3$
e. $845\ kg/m^3$

$$\rho' = \frac{M}{V'} = \frac{M}{V\left(1 + \frac{\Delta V}{V}\right)} = \frac{\rho}{1 + \frac{\Delta V}{V}} = \frac{955\ kg/m^3}{1 + 0.0284} = 928.6\ kg/m^3$$

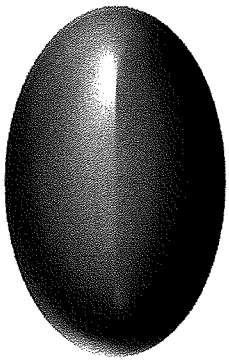
Consider two identical containers. Container A is filled with water to the top. Container B has a block of iron which sinks to the bottom, but the level of the water is also at the top.



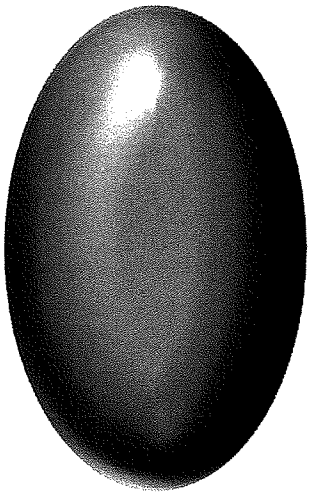
13) Which container weighs more?

a. *Container B*
b. *They both weigh the same*
c. *Container A*

The next two questions pertain to the situation described below.



Balloon at T_1



Balloon at T_2

You fill a balloon with $V_1 = 0.00159\ m^3$ of argon gas (*molar mass = 40 amu*) at $T_1 = 20^oC$. You heat the gas in the balloon, keeping the pressure constant.

17) At $T_2 = 31.5^oC$, what is the volume of the gas in the balloon?

a. $V_2 = 0.0025\ m^3$

(b.) $V_2 = 0.00165\ m^3$

c. $V_2 = 0.00153\ m^3$

$PV = nRT \Rightarrow \frac{V_1}{V_2} = \frac{T_1}{T_2} \Rightarrow V_2 = V_1 \frac{T_2}{T_1}$

$V_2 = 0.00159\ m^3 \times \frac{31.5 + 273}{20 + 273} = 0.00165\ m^3$

18) At $T_2 = 31.5^oC$, what is the RMS speed, v_{RMS}, of the argon atoms in the balloon? (*1 amu = 1.66x10^{-27} kg*)

a. $v_{RMS} = 140\ m/s$

b. $v_{RMS} = 308\ m/s$

(c.) $v_{RMS} = 436\ m/s$

$\frac{1}{2} m v_{rms}^2 = \frac{3}{2} kT$

$v_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23}\ J/K \times (31.5+273)K}{40 \times 1.66 \times 10^{-27}\ kg}}$

$= 435.7\ m/s$

24) At what speed, v_s, must a car drive towards a stationary observer so that the frequency heard by the observer, f_o, is twice that emitted by the source, f_s, i.e. $f_o = 2f_s$? The speed of sound is $v = 330\ m/s$.

a. $v_s = 187\ m/s$
b. $v_s = 165\ m/s$
c. $v_s = 212\ m/s$
d. $v_s = 375\ m/s$
e. $v_s = 100\ m/s$

25) You heat a metallic strip from $275\ K$ to $1248\ K$. If at $275\ K$ its length is $1.58\ m$ and the coefficient of linear expansion is $\alpha = 19 \times 10^{-6}\ K^{-1}$, what is the length of the strip at $1248\ K$?

a. $l = 2.37\ m$
(b.) $l = 1.61\ m$
c. $l = 0.79\ m$

$$\frac{\Delta L}{L} = \alpha \Delta T = 19 \times 10^{-6}\ K^{-1} \times (1248 - 275)\ K = 0.0185$$

$$L' = L\left(1 + \frac{\Delta L}{L}\right) = 1.58\ m \times (1 + 0.0185)$$

$$= 1.609\ m$$

26) We use a piston to compress $94\ ml$ of a gas at a pressure of $53\ Pa$ to a new volume of $19\ ml$ at constant temperature. What is the new pressure of the gas?

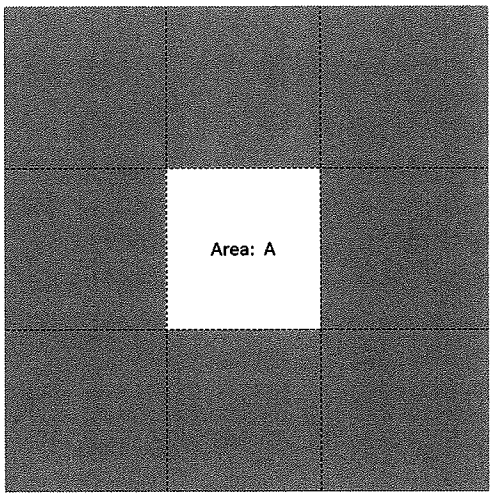
a. $P = 167\ Pa$
b. $P = 148\ Pa$
c. $P = 19\ Pa$
d. $P = 33.7\ Pa$
(e.) $P = 262\ Pa$

$$PV = nRT \Rightarrow P_1 V_1 = P_2 V_2 \Rightarrow P_2 = P_1 \frac{V_1}{V_2}$$

$$P_2 = 53\ Pa \times \frac{94}{19} = 262.2\ Pa$$

The next two questions pertain to the situation described below.

Consider this plate of aluminum at $T_1 = 20^oC$ with a square hole as shown in the diagram. The coefficient of linear thermal expansion is $\alpha = 23.1x10^{-6}\ K^{-1}$.



4) When the plate is heated to $T_2 = 350^o$ the hole will

a. *get smaller*
(b.) *get larger*
c. *stay the same*

5) If the hole has area $A = 1.5\ cm^2$ at $T_1 = 20^oC$, what is the area of the hole at $T_2 = 350^o$? (hint: The thermal expansion coefficient for an area is $\alpha_A = 2\ \alpha$)

(a.) $A_{new} = 1.52\ cm^2$
b. $A_{new} = 1.55\ cm^2$
c. $A_{new} = 1.48\ cm^2$

$$\frac{\Delta A}{A} = 2\alpha\Delta T = 2 \times 23.1 \times 10^{-6}\ K^{-1} \times (350 - 20)\ C$$

$$= 0.0152$$

$$A' = A\left(1 + \frac{\Delta A}{A}\right) = 1.5\ cm^2 \times (1.0152) = 1.52\ cm^2$$

The following question is by itself.

17. Two identical sirens are placed 30 meters away from you. From them you hear a sound of loudness β_0. How many sirens the same as these two sirens should be placed 60 m away from you to produce the sound of the same loudness β_0?

a. 5
b. 6
c. 7
d. 4
e. 8

The following question is by itself.

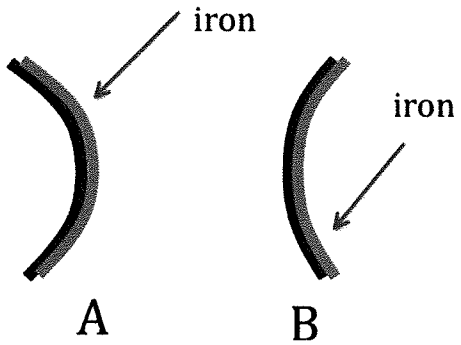
18. There is a siren at the side of a straight road. You drive a car toward it and then pass it by. You hear the frequency of the siren to change from $f_{before} = 860$ Hz to $f_{after} = 820$ Hz. What is the frequency of the siren measured by a stationary observer?

a. 840 Hz
b. 830 Hz
c. 850 Hz
d. 845 Hz
e. 835 Hz

The following question is by itself.

19. A bimetallic strip is made from an aluminum strip placed at the left and an iron strip placed at the right. The linear thermal expansion coefficient of aluminum is 1.6×10^{-5} /K and that of iron is 1.2×10^{-5} /K. The bimetallic strip is straight at 300 K. Now, the temperature is increased to 370K. Which way does the bimetallic strip bend, to the iron side (right) or to the aluminum side (left)?

a. leftward (A)
(b.) rightward (B)



The following question is by itself.

20. There is a cubic box of size a. When its temperature is raised from 230 K to 340 K, its surface area increases by 2.2 %. What is the % increase of its volume in the same situation?

$A \propto a^2$, $V \propto a^3$ $\Rightarrow$ $\frac{V}{A} \propto a$ $\Rightarrow$ $\frac{\Delta V/V}{\Delta A/A} \propto \Delta a/a = 1.1\%$

$\frac{\Delta V}{V} = 3.3\%$

a. 1.5 %
(b) 3.3 %
c. 2.2 %
d. 2.7 %
e. 4.4 %

The following question is by itself

21. An ideal gas thermometer is a small rigid container of volume 120 cm^3 containing 0.03 moles of ideal gas. From its pressure the temperature is measured. The thermometer is dipped in a liquid and, after thermal equilibrium is reached, the pressure of the thermometer is 293 kPa. What is the temperature of the liquid?

$120 \times 10^{-6}\ m^3$

$PV = nRT \Rightarrow T = \frac{PV}{nR} = \frac{293\ kPa \times 120\ cm^3}{0.03\ moles \times 8.314\ J/K/mole}$

$= 141.\ K$

a. 390 K
(b.) 141 K
c. 297 K
d. 401K
e. 323 K

The next two questions refer to the same situation.

A tank of volume 1.3 m^3 contains an ideal gas consisting of a chemical species A, whose pressure is P = 490 kPa and temperature T = 320 K.

22. How many molecules are there in the tank?

$PV = NkT \Rightarrow N = \frac{PV}{kT} = \frac{490\ kPa \times 1.3\ m^3}{1.38 \times 10^{-23}\ J/K \times 320\ K}$

$= 1.44 \times 10^{26}$

a. 0.31×10^{24}
b. 1.44×10^{24}
c. 1.12×10^{25}
(d.) 1.44×10^{26}
e. 0.31×10^{26}

23. The root-mean-square velocity of the gas molecules is 257 m/s. What is the molecular mass of chemical species A? Express your answer in unit of unified atomic mass u. 1 u = 1.66×10^{-27} kg.

$\frac{1}{2} m v_{rms}^2 = \frac{3}{2} kT$

$m = \frac{3kT}{v_{rms}^2} = \frac{3 \times 1.38 \times 10^{-23}\ J/K \times 320\ K}{(257\ m/s)^2}$

$= 2.00 \times 10^{-25}\ kg = 120.5\ u$

a. 163 u.
(b.) 121 u.
c. 49 u.
d. 82 u.
e. 103 u.

Check to make sure that you bubbled in all of your answers.
Did you bubble in your name, network id and exam version?

The following 2 questions concern related physical situations:

A siren gives a loudness β_7 when it is 7 m away and β_9 when it is 9 m away.

4. Find the difference $\beta_7 - \beta_9$.

a. $\beta_7 - \beta_9 = 0.98$ dB.
b. $\beta_7 - \beta_9 = 1.58$ dB.
c. $\beta_7 - \beta_9 = 2.18$ dB.

5. A single siren 9 meters away makes a sound of loudness β_9. What is the loudness, β of 3 sirens, identical to the first one, placed at the same location?

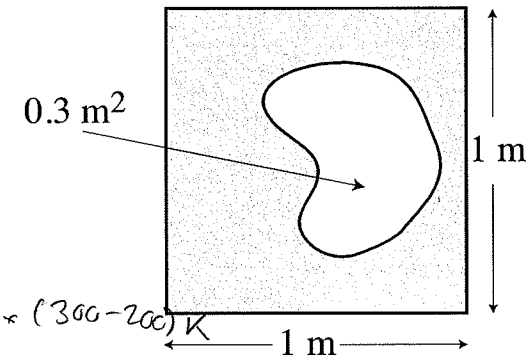
a. $\beta = \beta_9 + 4.8$.
b. $\beta = 3\,\beta_9$.
c. $\beta = 4.8\,\beta_9$.

6. You drive a car at a constant speed along a road. On the roadside is a stationary siren whose frequency observed by a bystander is f_0. When you are approaching the siren, you hear the frequency $f_b = 740$ Hz and when you are leaving the siren, you hear the frequency $f_a = 690$ Hz. Assume that the speed of sound is 330 m/s. What is the frequency f_0 of the siren?

a. 671 Hz
b. 690 Hz
c. 702 Hz
d. 715 Hz
e. 740 Hz

7. On a 1 m square plate is a hole of area $A = 0.3\ m^2$ at $T = 200$ K. The plate is made of a material whose linear thermal expansion coefficient is $\alpha = 13 \times 10^{-6}\,K^{-1}$. What is the increase ΔA of the area of the window at $T = 300$ K compared with that at $T = 200$ K?

a. $\Delta A = 5.3 \times 10^{-4}\ m^2$
(b.) $\Delta A = 7.8 \times 10^{-4}\ m^2$
c. $\Delta A = 9.3 \times 10^{-4}\ m^2$
d. $\Delta A = 11.2 \times 10^{-4}\ m^2$
e. $\Delta A = 13.5 \times 10^{-4}\ m^2$



$\frac{\Delta A}{A} = 2\alpha\Delta T = 2 \times 13 \times 10^{-6}\ K^{-1} \times (300-200)\ K$

$= 0.0026$

$\Delta A = A \times 0.0026 = 0.3\ m^2 \times 0.0026 = 0.00078$

The following two questions concern related physical situations:

In a container of volume V = 0.5 m^3 is 0.8 kg of an ideal gas. Its pressure is P = 1. 25 × 10^5 Pa at temperature T = 290 K.

8. What is the molecular mass M of the molecules making the gas?

a. M = 22.3 amu
(b.) M = 30.8 amu
c. M = 33.5 amu
d. M = 41.1 amu
e. M = 49.0 amu

$$PV = NkT \Rightarrow N = \frac{PV}{kT} = \frac{1.25\times10^5\ Pa \times 0.5\ m^3}{1.38\times10^{-23}\ J/K \times 290\ K}$$

$$= 1.56 \times 10^{25}$$

$$0.8\ kg = N \times M \Rightarrow M = \frac{0.8\ kg}{1.56\times10^{25}} = 5.13\times10^{-26}\ kg$$

$$= 30.9\ amu$$

$$(1\ amu = 1.66\times10^{-27}\ kg)$$

9. What is the ratio of the root mean square velocity v_{290} of the molecules at T = 290 K, and that v_{580} at T = 580 K?

a. v_{580}/ v_{290} = 1.21
b. v_{580}/ v_{290} = 1.31
(c.) v_{580}/ v_{290} = 1.41
d. v_{580}/ v_{290} = 1.71
e. v_{580}/ v_{290} = 2.00

$$\frac{1}{2} m v_{rms}^2 = \frac{3}{2} kT$$

$$\left(\frac{v_{rms}^{580}}{v_{rms}^{290}}\right)^2 = \frac{T^{580}}{T^{290}}$$

$$\frac{v_{rms}^{580}}{v_{rms}^{290}} = \sqrt{\frac{T^{580}}{T^{290}}} = \sqrt{\frac{580}{290}} = \sqrt{2} = 1.41$$

This exam continues on the next page.

13) A sound wave is

a. An electromagnetic wave
b. A transverse wave
c. A longitudinal wave

14) If the frequency of a wave is 170 *Hz*, and the wavelength is 2 *m*, what is the velocity of the wave?

a. 85 *m/s*
b. 340 *m/s*
c. 4 *m/s*
d. 34 *m/s*
e. 1360 *m/s*

15) If a sound source moves in the direction of a stationary observer, the observer hears the sound wave at a greater

a. Velocity
b. Period
c. Wavelength
d. Amplitude
e. Frequency

16) A cylinder is capped by a piston such that it contains a volume of 20 *ml* of an ideal gas at a pressure of 40 *psi*. If the volume is decreased to 10 *ml*, what is the new pressure? Assume the temperature is constant.

$$PV = nRT \Rightarrow P_1V_1 = P_2V_2 \Rightarrow P_2 = P_1 \frac{V_1}{V_2}$$

a. 20 *psi*
(b) 80 *psi*
c. 40 *psi*

$$P_2 = 40\ psi \times \frac{20}{10} = 80\ psi$$

17) The temperature of an ideal gas quadruples. How does the root-mean-square speed of the gas molecules of the hotter gas, v'_{rms}, compare to the root-mean-square molecular speed of the cooler gas, v_{rms}?

(a.) $v'_{rms} = 2v_{rms}$
b. $v'_{rms} = v_{rms}$
c. $v'_{rms} = 16v_{rms}$
d. $v'_{rms} = 4v_{rms}$
e. $v'_{rms} = 0.5v_{rms}$

$\frac{1}{2} m v_{rms}^2 = \frac{3}{2} kT \Rightarrow \left(\frac{v'_{rms}}{v_{rms}}\right)^2 = \frac{T'}{T}$

$v'_{rms} = v_{rms} \times \sqrt{\frac{T'}{T}} = v_{rms}\sqrt{4}$

$= 2v_{rms}$

18) A piece of metal with coefficient of expansion $\alpha = 16 \times 10^{-6} K^{-1}$ at $273K$ has length 1 m. By how much does the length change if it is heated to 900 K?

a. 1 *mm*
(b.) 10 *mm*
c. 100 *mm*

$\frac{\Delta L}{L} = \alpha \Delta T = 16 \times 10^{-6} K^{-1} \times (900 - 273) K$

$= 0.01$

$\Delta L = L \times 0.01 = 1m \times 0.01 = 10 \text{ mm}$

19) A ring of metal with a circular hole in the middle is heated. As a result of heating, the diameter of the hole

a. Decreases
b. Stays the same
(c.) Increases

20) An observer measures the loudness of a speaker to be 50 *dB*. What would be the loudness of 100 identical speakers together?

a. 70 *dB*
b. 250 *dB*
c. 55 *dB*
d. 150 *dB*
e. 500 *dB*