Natural Constants

- \( N_A = 6.02 \times 10^{23} \)
- \( k_B = 1.38 \times 10^{-23} \) J/K
- \( R = 8.31 \) J/mol.K
- \( G = 6.67 \times 10^{-11} \) N m\(^2\)/kg\(^2\)
- \( g = 9.8 \) m/s\(^2\)
- \( m_{\text{earth}} = 5.98 \times 10^{24} \) kg
- \( R_{\text{earth}} = 6.38 \times 10^6 \) m
- log-rules:
  - \( \log (ab) = \log (a) + \log (b) \)
  - \( \log (a/b) = \log (a) - \log (b) \)
1. A block of mass \( M \) and volume \( V \) is hung on a scale and completely immersed in a beaker of mass \( m_b \) containing oil of mass \( m_o \) and density \( \rho_o \). The beaker is placed on the bottom scale. What is the reading on the bottom scale?

   a) \( m_g \)
   b) \( (m_o + m_b)g \)
   c) \( (m_o + m_b + M)g \)
   d) \( (m_o + m_b + \rho_o V)g \)
   e) \( Mg \)

\[ N = m_g + m_o g + B \]

\[ B = \rho_o V g \]

2. A metal sphere filled with an ideal gas is cooled from 50 °C to -50 °C. What is the corresponding change in the density of the gas during this process?

   a) The density decreases by a factor 2.0
   b) The density decreases by a factor 1.78
   c) The density decreases by a factor 1.45
   d) The density decreases by a factor 4.0
   e) The density changes by less than 1 %

   \[ \text{mass is fixed} \]
   \[ \text{volume is nearly fixed} \]

3. A cube of wood of density 0.64 g/cm³ is 10 cm on a side. When placed in water of density 1.00 g/cm³, what height of the block will float above the surface?

   a) 7.8 cm
   b) 3.6 cm
   c) 6.4 cm
   d) 2.2 cm
   e) 5.0 cm

\[ B = \rho_w V_{\text{disp}} \]

\[ \rho_w g = \rho_{\text{wood}} V_{\text{block}} \]

\[ V_{\text{disp}} = 0.64 V_{\text{wood}} \]

\[ V_{\text{water}} = 0.36 V_{\text{wood}} \]

4. 0.100 kg of ice of 0 °C and 0.100 kg of steam of 100 °C are put together. What is the final temperature? (NOTE: Specific heat of ice is 2090 J/kg·°C. Specific heat of water is 4186 J/kg·°C. Specific heat of steam is 2010 J/kg·°C. Latent heat of fusion of water is 333,000 J/kg. Latent heat of vaporization of water is 2,260,000 J/kg.)

   a) 100 °C
   b) 90 °C
   c) 50 °C
   d) 80 °C
   e) 0 °C

\[ Q_{\text{ice} \rightarrow \text{melting} \text{ water}} = mL_{\text{ice}} = 0.1 \times 333,000 = 33,300 \text{ J} \]

\[ Q = m \omega \Delta T = 0.1 \times 4186 \text{ J} = 418.6 \text{ J} \]

\[ Q_{\text{ice} \rightarrow \text{steam}} = 75,160 \text{ J} \]

Condensing steam would give 0.1 x 2,260,000 = 226,000 J

So most steam remain steam and \( T_{\text{final}} = 100 °C \).
5. The noble gases, listed by increasing molecular weight, are He, Ne, Ar, Kr, Xe, and Rn. Samples of 1 mole each of these gases are placed in separate containers and heated to 300 °K. Which of the following statements is true about the internal energy and rms speed?

a) He has the greatest internal energy, and Rn has the greatest rms speed.

b) Rn has the greatest internal energy, and He has the greatest rms speed.

c) All gases have the same internal energy, and Rn has the greatest rms speed.

d) All gases have the same internal energy, and He has the greatest rms speed.

e) All gases have the same internal energy and the same rms speed.

6. A pure sample of $^{226}\text{Ra}$ contains $3.0 \times 10^{13}$ atoms of the isotope. If the half-life of $^{226}\text{Ra}$ is 1600 years, what is the activity of this sample?

- a) $1.3 \times 10^{10}$ decays/year
- b) $1.9 \times 10^{10}$ decays/year
- c) $4.1 \times 10^2$ decays/year
- d) $4.8 \times 10^{16}$ decays/year
- e) $8.1 \times 10^6$ decays/year

\[ N_d = \lambda N_0 \]

\[ \lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{1600 \text{ years}} = 0.0004332 \text{ decays/year} \]

\[ R = 0.0004332 \times 3.0 \times 10^{13} = 1.30 \times 10^{10} \text{ decays/year} \]

7. When an artery contains a constricted region due to plaque, how does the pressure in this region compare to the unconstricted region adjacent?

a) Since this is a closed system, the pressure is the same in both regions

b) In the constricted region the blood moves at a higher speed than in the unconstricted region resulting in an increased pressure

c) In the constricted region the blood moves at a higher speed than in the unconstricted region resulting in a decreased pressure

d) In the constricted region the blood moves at a lower speed than in the unconstricted region resulting in an increased pressure

e) In the constricted region the blood moves at a lower speed than in the unconstricted region resulting in a decreased pressure

\[ A \text{ velocity} = \text{constant} \Rightarrow \text{velocity is larger in constriction} \]

\[ \text{Since } P + \rho gh + \frac{1}{2} \rho u^2 = \text{constant} \Rightarrow P \text{ in constriction is smaller} \]
8. A 0.2 kg aluminum plate, initially at 20 °C, slides down a 15-m-long surface, inclined at a 26 degree angle to the horizontal. The force of kinetic friction exactly balances the component of gravity down the plane so that the plate, once started, slides down at constant velocity. If 90% of the mechanical energy of the system is absorbed by the aluminum, what is its temperature increase at the bottom of the incline? (specific heat for aluminum is 900 J/kg°C)

\[ \text{HEAT DUE TO WORK BY FRICTION} \]

- a) 0.132 °C
- b) 0.064 °C
- c) 0.32 °C
- d) 1.07 °C
- e) 58 °C

\[ F_{\text{friction}} = \mu mg \cos \theta = 0.2 \times 9.8 \times \cos 26 = 0.859 \text{ N} \]

\[ W_{\text{friction}} = F \Delta x = 0.859 \times 15 = 12.89 \text{ Joules} \]

\[ q = m c_A \Delta T \Rightarrow \Delta T = \frac{q}{m c_A} \]

\[ \Rightarrow \Delta T = \frac{0.90 \times 17.89}{11.60} = 1.56 \text{ °C} \]

9. A drum reaches a sound intensity level of 95 decibels if you are 4.0 meters away from it. What is the intensity level of two of the same drums together as heard by a listener at 8.0 meters?

- a) 92 dB
- b) 95 dB
- c) 101 dB
- d) 98 dB
- e) 89 dB

\[ P_1 = 10 \log \frac{I_1}{I_0} = 95 \text{ dB}; \quad P_2 = 10 \log \frac{I_2}{I_0} = 10 \log \frac{1}{2} = 5 \text{ dB} \]

\[ P = 10 \log \left( \frac{10^{9.5} + 10^{5}}{2} \right) = 91.99 \text{ dB} \]

10. A monoatomic gas expands from A to B along a path indicated in the P-V diagram. Temperature at A is 300 °K. Pressure at A is 4.00 ATM and pressure at B is 1.50 ATM. (1 ATM = 1.013 \times 10^5 Pa, 1 liter = 10^-3 m^3). Is heat added to the gas or extracted and what is the temperature at B?

\[ T_B = \frac{3}{4} T_A = 225 \text{ °K} \]

- a) heat is added, \( T_B = 400 \text{ °K} \)
- b) heat is added, \( T_B = 225 \text{ °K} \)
- c) heat is extracted, \( T_B = 400 \text{ °K} \)
- d) heat is extracted, \( T_B = 225 \text{ °K} \)
- e) no heat is added or extracted and \( T_B = 225 \text{ °K} \)

\[ W_{\text{ex}} = -A \int_{A}^{B} = -\left[ 1.5x^2 + \frac{1}{3} 2.5x^2 \right]_{0}^{1.013} = -557.2 \text{ Joule} \]

\[ U_A = \frac{3}{2} P_A V_A = 1.5 \times 4 \times 2 \times 101.3 = 1215.6 \text{ Joule} \]

\[ U_B = \frac{3}{2} P_B V_B = 1.5 \times 1.5 \times 4 \times 101.3 = 911.7 \text{ Joule} \]

\[ \text{SECOND LAW: } U_A + Q_{\text{add}} + W_{\text{ex}} = U_B \]

\[ 1215.6 + Q_{\text{add}} - 557.2 = 911.7 \]

\[ Q_{\text{add}} = 253.3 \text{ Joule} \]
11. An unstable nucleus follows a decay scheme where the final stable nucleus is a different isotope of the original nucleus. For which decay scheme is this the case?
   - Isotope: Same # Different N
   a) gamma decay
   b) alpha decay followed by two beta (electron) decays
   c) a beta (electron) decay followed by an alpha decay
     \[ \alpha : Z \rightarrow Z-2 \]
   d) a beta (electron) decay followed by neutron decay
     \[ \beta : Z \rightarrow Z+1 \]
   e) a beta (electron) decay
     \[ Z \rightarrow Z+2 \]

12. A gasoline engine with an efficiency of 33.1% operates between a high temperature \( T_1 \) and a low temperature \( T_2 = 350 \) K. If this engine operates with the ideal efficiency of a heat engine, what is the high-side temperature \( T_1 \)?
   a) 1057 K
   b) 782 K
   c) 1169 K
   d) 523 K
   e) 434 K

13. Let the mechanical energy of a harmonic oscillator be \( E_0 \) and the maximum displacement be \( x_0 \). When the displacement is \( x_0/2 \), what is the kinetic energy?
   a) \( E_0/2 \)
   b) \( E_0/4 \)
   c) \( 3E_0/4 \)
   d) \( E_0 \)
   e) \( E_0/8 \)

14. When the mass in a spring-mass system is doubled but the maximum displacement is not changed, what will be the total energy? Let \( E_0 \) be the original total energy.
   a) \( E_0/2 \)
   b) \( E_0/4 \)
   c) \( 2E_0 \)
   d) \( E_0 \)
   e) \( 4E_0 \)
15. A string has a linear mass density \( \mu \) at \( x < 0 \) but \( 4 \mu \) at \( x > 0 \). Tension \( T \) is the same for all \( x \). A wave of frequency \( f \) and wavelength \( \lambda \) is traveling from negative \( x \) towards positive \( x \). When the wave moves into the positive \( x \) region, how will the wavelength \( \lambda \) change?

a) \( \lambda \)  

b) \( 4 \lambda \)  

c) \( 2 \lambda \)  

d) \( \lambda/4 \)  

- e) \( \lambda/2 \)  

\[ v_{\text{LEFT}} = \sqrt{\frac{T}{\mu}} \quad v_{\text{RIGHT}} = \sqrt{\frac{T}{4\mu}} = \frac{v_{\text{LEFT}}}{2} \]

Since \( f \) remains same  

And  
\[ \lambda = \frac{v}{f} \]

\[ \lambda_{\text{RIGHT}} = \frac{1}{2} \lambda_{\text{LEFT}} \]