Natural Constants

- \( N_A = 6.02 \times 10^{23} \)
- \( k_B = 1.38 \times 10^{-23} \text{ J/K} \)
- \( R = 8.31 \text{ J/mol.K} \)
- \( G = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2 \)
- \( g = 9.8 \text{ m/s}^2 \)
- \( e = 1.602 \times 10^{-19} \text{ C} \)
- \( m_e = 9.11 \times 10^{-31} \text{ kg} \)
- \( m_p = 1.67 \times 10^{-27} \text{ kg} \)
- \( k_e = 8.99 \times 10^9 \text{ N m}^2/\text{C}^2 \)
- \( \epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N m}^2 \) (permittivity of free space)
- \( m_{\text{earth}} = 5.98 \times 10^{24} \text{ kg} \)
- \( R_{\text{earth}} = 6.38 \times 10^8 \text{ m} \)
- \( c = 3.0 \times 10^8 \text{ m/s} \)
1. A bullet of 50 gram is shot into a wooden block of 500 gram mass that is initially at rest and mounted on frictionless wheels. After the bullet is embedded in the wood the block moves with speed 30 m/s. How fast did the bullet go initially?
   a) 3.0 m/s
   b) 30 m/s
   c) 300 m/s
   d) 330 m/s
   e) 600 m/s

2. The force between two protons of charge $1.6 \times 10^{-19}$ C, in a nucleus where they are a distance $4.0 \times 10^{-15}$ m apart is
   a) $14.4 \text{ N}$, attractive
   b) $1.76 \times 10^{-14} \text{ N}$, attractive
   c) $14.4 \text{ N}$, repulsive
   d) $1.76 \times 10^{-14} \text{ N}$, repulsive
   e) $9.00 \times 10^{19} \text{ N}$, attractive

3. Charges $q_1$, $q_2$, $q_3$, and $q_4$, are placed at the corners of a square of side 20 cm. Given that $q_1 = q_2 = q_3 = 5 \mu \text{C}$, and $q_4 = -5 \mu \text{C}$, what is the direction of the electric field at the center of the square?

   a) towards $q_1$
   b) towards $q_2$
   c) towards $q_3$
   d) towards $q_4$
   e) none of the other answers
4. Two charges Q and -2Q are located respectively at A and B as shown in
   the figure. Where on the drawn line can the electric field be zero?
   a) in region AB and to the right of B
   b) only to the right of B
   c) to the left of A and in region AB
   d) only to the left of A
   e) only in the region AB

\[ E_A + E_R = 0 \]
\[ |E_A| < |E_R| \]

5. Four charges are fixed at the corners of a square of side 1 m. The electric
   potential at the center of the square is given by

\[ \begin{align*}
   A \rightarrow P: \\
   V_Q + V_{-Q} &= 0 \\
   V_{2Q} + V_{-2Q} &= 0 \\
   V_{4Q} &= 0 \\
   \text{Total} &= 0
\end{align*} \]

6. If an object is a distance 2f in front of a converging lens of focal length f,
   the image is
   a) twice the size of the object and inverted
   b) the same size as the object and erect
   c) twice the size of the object and erect
   d) four times the size of the object
   e) the same size as the object and inverted

\[ \frac{1}{2f} + \frac{1}{2f} = \frac{1}{f} \]

7. Two different monatomic gasses at the same temperature and with the
   same number of molecules must have the same

   a) pressure, depends on \( V \)
   b) average velocity, depends on mass \( \frac{1}{2} mv^2 = \frac{3}{2} kT \)
   c) heat capacity, depends on process
   d) internal energy, \( \frac{3}{2} kT = \text{same} \)
   e) ability to do work, depends on process
8. Images of real objects formed by a diverging lens are always
   a) enlarged
   b) virtual
   c) real
   d) inverted
   e) reduced and real

9. The position of an object moving with simple harmonic motion is given by
   \[ x(t) = 6 \cos(4\pi t), \] where \( x \) is in meters and \( t \) is in seconds. What is the
   period of the oscillating system?
   a) 4 s
   b) 0.25 s
   c) 2 s
   d) 0.5 s
   e) 0.67 s

10. An object 6 cm high is placed 10 cm in front of a converging lens, \( f = 8 \) cm. The image is
    a) 40 cm beyond the lens, inverted, real, and 24 cm high
    b) 4.4 cm beyond the lens, inverted, real, and 6.3 cm high
    c) 4.4 cm beyond the lens, upright, real, and 24 cm high
    d) 40 cm beyond the lens, inverted, virtual, and 24 cm high
    e) 40 cm beyond the lens, upright, real, and 24 cm high
    \[ \frac{\omega_o}{\omega_i} = \frac{5}{4} \] (Ref A1)

11. The index of refraction of magnesium oxide is 1.75. This means that
    a) when light passes from air to magnesium oxide its speed decreases
       by 75\% \[ n = 1.75 = 5. \]
    b) when light passes from air to magnesium oxide its wavelength increases.
    c) the frequency of light in air is reduced by a factor 4/7 as it enters
       magnesium oxide \( f \) is \textbf{NOT} \textbf{CHANGED}
    d) its wavelength is unchanged as light passes from air to magnesium
       oxide \( \lambda \text{ INCREASES}
    e) the frequency remains unchanged when light passes from air to mag-
       nesium oxide but its wavelength is divided by 1.75.
12. Four balls of different masses, \( m_1 < m_2 < m_3 < m_4 \), are thrown from the top of a building at different angles, but all with the same initial speed. Neglecting air resistance, which of the balls has the greatest speed just before it hits the ground?

\[
\frac{1}{2} m_i v_i^2 + m_i g h_i = \frac{1}{2} m_i (v_i')^2
\]

a) \( v_i^2 + 2 g h_i = (v_i')^2 \)

b) \( v_i^2 \) \( \text{SAME INITIAL } v_i \)

c) \( v_i \) \( \text{SAME FINAL } v_i' \)

d) All four balls have the same speed just before they hit the ground.

e) \( \text{SAME INITIAL } v_i \)

13. A parallel-plate capacitor of capacitance, \( C \), is attached to a battery of voltage, \( V \). The energy stored on the capacitor is 4 J. We then carry out the following steps. While the capacitor is still connected to the battery, the separation of the two plates is doubled. The battery is then disconnected and while the capacitor remains disconnected from the battery, the two plates are brought back to their original separation. After this last step, what is then the energy stored on the capacitor?

\[
E_i = \frac{1}{2} C V^2
\]

a) \( 4 J \) \( \text{STEP 1} \rightarrow \text{STEP 2} \rightarrow \text{STEP 3} \)

b) \( 8 J \)

c) \( 1 J \) \( \frac{C_2}{C_1} = \frac{1}{2} \)

d) \( 2 J \) \( \frac{C_3}{C_2} = \frac{1}{2} \)

e) \( 16 J \) \( \frac{E_3}{E_2} = \frac{1}{4} \)


\[
B = m g - \frac{24 \times 9.8}{3} = 238 N
\]

a) 235 N
b) 157 N
c) 78 N
d) 16 N
e) Need volume of box and / or density of liquid to determine the force.
15. The lowest frequency a person can hear is about 20 Hz. How long should an organ pipe, open at both ends, be so that it produces a 20 Hz sound as its fundamental frequency? Use velocity of sound \( v = 344 \text{ m/s} \).

   a) 34.4 m
   b) 17.2 m
   c) 8.6 m
   d) 4.3 m
   e) 2.15 m

   \[ v = \lambda \frac{L}{2} \rightarrow 344 = 2 \times 20 \rightarrow L = 8.6 \text{ m} \]

16. If you add 600 kJ of heat to 600 g of water at 60.0°C, how much water is left in the container? The latent heat of vaporization of water is \( 22.6 \times 10^5 \) J/kg and the heat capacity of water is 4186 J/(kg K).

   a) 379 g
   b) 258 g
   c) 600 g
   d) none
   e) 401 g

   \[ Q = 600,000 \text{ J} \]
   \[ Q_{\text{heat}} = Q - Q_{100} = 499,536 \text{ J} \]
   \[ m = \frac{Q}{c} = \frac{600,000}{4186} = 142,321 \text{ g water} \]
   \[ m = 0.221 \text{ kg water} \]
   \[ \text{WATER LEFT} : 0.600 - 0.221 = 0.379 \]

17. A 500 kg cannon on a horizontal platform fires a 4 kg projectile at a speed of 500 m/s at an angle of 30 degrees above the horizontal. What is the recoil speed of the cannon?

   a) 1.73 m/s
   b) 2.00 m/s
   c) 6.00 m/s
   d) 3.46 m/s
   e) 4.00 m/s

   \[ V_c = \frac{V_p}{\tan 30°} \]
   \[ V_{\text{recoil}} = V_{\text{cannon}} = V_{\text{horizontal}} = \frac{500 \text{ m/s}}{\tan 30°} = 2.46 \text{ m/s} \]

18. The deepest point in the Pacific Ocean is 11,033 m, in the Mariana Trench. What is the water pressure at that depth? The density of sea water is 1025 kg/m³.

   a) \( 5.55 \times 10^7 \) N/m²
   b) \( 8.88 \times 10^7 \) N/m²
   c) \( 1.11 \times 10^8 \) N/m²
   d) \( 2.22 \times 10^8 \) N/m²
   e) \( 5.55 \times 10^8 \) N/m²

   \[ P = \rho g \rho \]
   \[ = 1025 \times 9.8 \times 11,033 = 1025 \times 9.8 \times 11,033 \times P_a \]
19. A projectile is fired from the top of a tower with velocity 20 m/s at 45° below the horizontal. It hits the ground 80 m from the base of the tower. The height of the tower is about

\[ \text{HORIZONTAL} \]
\[ x = v_x t \]
\[ t = \frac{80}{u_x} = 5.66 \text{ sec} \]

\[ \text{a)} \ 38 \text{ m} \]
\[ \text{b)} \ 77 \text{ m} \]
\[ \text{c)} \ 118 \text{ m} \]
\[ \text{d)} \ 157 \text{ m} \]

\[ \text{e)} \ 237 \text{ m} \]
\[ \text{vertical} \]
\[ v_{0y} t + \frac{1}{2} a t^2 \]
\[ \text{height} = u_y \times 5.66 + \frac{q}{2} \times 5.66^2 \]
\[ = 80 \text{ m} + 156.8 = 236.8 \text{ m} \]

20. Light goes from water (n=1.33) to diamond (n=2.419). It hits the surface of the diamond under 45° with the normal. Inside the diamond the light propagates under an angle θ with the normal. The angle θ is

\[ \text{a)} \ \theta \leq 20° \]
\[ \text{b)} \ 20° \leq \theta \leq 40° \]
\[ \text{c)} \ 40° \leq \theta \leq 60° \]
\[ \text{d)} \ 60° \leq \theta \leq 90° \]
\[ \text{e)} \ \text{it does not enter the diamond} \]

21. Three boxes rest side by side on a smooth, horizontal floor. Their masses are 5 kg, 3 kg, and 2 kg, with the 3 kg mass in the center. A person pushes with a force of 50 N on the 2 kg mass. What is the magnitude of the force of the 3 kg box on the 5 kg box?

\[ \text{a)} \ 25 \text{ N} \]
\[ \text{b)} \ 40 \text{ N} \]
\[ \text{c)} \ 50 \text{ N} \]
\[ \text{d)} \ 0 \text{ N} \]
\[ \text{e)} \ 15 \text{ N} \]

**Whole System:**

\[ F_{\text{net}} = ma \]
\[ \sum F = (2+3+5) a \rightarrow a = 5 \text{ m/s}^2 \]

**3 kg mass:**

\[ F_{\text{net}} = ma \]
\[ F_{3on5} = 5 \times 5 = 25 \text{ N} \]
22. A child is riding a merry-go-round, which completes one revolution every 8.36 s. The child is standing 4.65 m from the center of the merry-go-round. What is the magnitude of the centripetal acceleration of the child?

- a) 1.24 m/s²
- b) 0.267 m/s²
- c) 0.657 m/s²
- d) 0.556 m/s²
- e) 2.63 m/s²

\[ T = \frac{2\pi R}{\theta} = \frac{2\pi \cdot 4.65}{0.36} \approx 3.31 \text{ m/s}^2 \]

23. A horse pulls a cart. The magnitude of the force of the horse on the cart is F₁ and the magnitude of the force of the cart on the horse is F₂. Which of the following is true?

- a) If the horse and the cart are accelerating, F₁ is greater than F₂
- b) F₁ and F₂ are equal only if the horse and the cart move at constant velocity
- c) The net force on the horse must be less than F₂
- d) None of the other statements is true
- e) F₁ and F₂ are always equal

\[ \mathbf{F}_1 = \mathbf{F}_{\text{HORSE ON CART}} \\
\mathbf{F}_2 = \mathbf{F}_{\text{CART ON HORSE}} \]

24. What is the temperature T of 2.0 moles of an ideal gas with a volume of 0.30 m³ and a pressure of 1.0 × 10⁴ Pa?

- a) \( T \leq 100 \text{ K} \)
- b) \( 100 \text{ K} < T \leq 200 \text{ K} \)
- c) \( 200 \text{ K} < T \leq 300 \text{ K} \)
- d) \( 300 \text{ K} < T \leq 400 \text{ K} \)
- e) \( 400 \text{ K} < T \)

\[ n = 2 \\
U = 0.3 \text{ m}³ \\
\rho = 1.0 \times 10^4 \text{ Pa} \\
\frac{pU}{\sqrt{2}} = \frac{1.0 \times 10^4 \times 0.3}{2 \times 0.31} = 180.5 \text{ K} \]

25. Consider a gas in a container having a moveable piston. The gas expands isothermally, pushing the piston and doing 214 J of work. Which of the following is true?

- a) The change in the internal energy of the gas cannot be determined, since we need the initial and final volumes to determine Q.
- b) The internal energy decreases by 214 J.
- c) The internal energy is unchanged. \( W_{\text{gas}} = W_1 = W_2 = 0 \Rightarrow U = \frac{3}{2} nRT \)
- d) The added heat Q is zero.
- e) The internal energy of the gas increases by 214 J.

\[ W = 214 \text{ J} \\
W_{\text{gas}} = (Q_{\text{app}} = 214 \text{ J} \]

\[ P \]

\[ U \]
26. A roller coaster coasts around a vertical, circular loop of radius 10 m. What is the minimum speed that the car must have at the bottom of the loop so that it makes it around the top of the loop without losing contact with the track? (There is no friction nor propulsion, and the car may be treated as a point particle.)

\[ \frac{1}{2} m v_B^2 = \frac{1}{2} m v_T^2 + 2\, mg R \]

\[ v_T^2 = \frac{v_B^2 - 4\, g R}{4\, g R} \Rightarrow v_B = \sqrt{\frac{g R}{4}} \]

a) 22.1 m/s  

b) 20.0 m/s  

c) 9.9 m/s  

d) 24.0 m/s  

e) 26.4 m/s

27. We start with 5 moles of an ideal monatomic gas with an initial temperature of 131°C. The gas expands and, in the process, absorbs an amount of heat equal to 1280 J and does an amount of work equal to 2040 J. What is the final temperature of the gas?

\[ n = 5 \quad T_i = 131°C = 404 \, ^°K \]

\[ W_{gy} = 2040 \, J \quad Q_{add} = 1280 \, J \]

a) 119 °C  

b) 125 °C  

c) 131 °C  

d) 142 °C  

e) 184 °C

28. An isotope of krypton has a half-life of 3 minutes. A sample of this isotope produces 1200 counts per second in a Geiger counter. Determine the number of counts per second after 15 minutes.

\[ a) 19 \quad b) 37 \quad c) 75 \quad d) 600 \quad e) 1200 \]

\[ t = 0 \text{ min} \quad \text{Counts/sec} \]

\[ t_{(min)} = 1200 \quad 600 \quad 300 \quad 150 \quad 75 \quad 37.5 \]

\[ T_f = 131 - 12.2 \]

\[ T_f = 118.8 \]

\[ T_f = 118.8 \]
29. Two parallel conducting plates are separated by 5 cm. The potential difference is kept at 200 Volt. How much work is needed to move an electron from the 200 Volt plate to the 0 Volt plate?

\[ W = q(V_2 - V_1) \]

a) \(-1.6 \times 10^{-19}\) J  

b) \(1.6 \times 10^{-19}\) J  

c) \(-3.2 \times 10^{-17}\) J  

d) \(3.2 \times 10^{-17}\) J  

e) zero  

30. A mass of 2.0 kg is placed against a horizontal spring that is 0.5 m compressed. Then the system is released. The mass accelerates and detaches from the spring and goes up a frictionless incline. Its maximum height is 2.55 m above the horizontal. What is the spring constant?

\[ \Delta x = \frac{m}{k} \]

a) \(k \leq 50\) N/m  

b) \(50\) N/m \(< k \leq 150\) N/m  

c) \(150\) N/m \(< k \leq 250\) N/m  

d) \(250\) N/m \(< k \leq 350\) N/m  

e) \(350\) N/m \(< k \)

\[ \text{PE}_{\text{spring}} = \text{KE}_{\text{released}} = \text{PE}_{\text{gravity}} \]

\[ \frac{1}{2} k (\Delta x)^2 = \frac{1}{2} m u^2 = m g h \]

\[ h = \frac{2 m g h}{(\Delta x)^2} = \frac{2 \times 9.8 \times 2.55}{0.5^2} = 399.84 \frac{N}{m} \]