1. An aluminum electric tea kettle has a 1500-W heating coil. How long will it take to heat up 1 kg of water from 18°C to 98°C in this kettle? (specific heat of water is 4186 J/kg°C)

\[ t = \frac{mc}{P} = \frac{1120 \times 4186 \times (98-18)}{1500} \]

Ans. 4 minutes

2. A 320-g piece of metal alloy at 130°C is dropped into the light calorimeter containing 178 g of water at 15°C. The final temperature of the system is 30°C. What is the specific heat of the metal?

\[ C = \frac{m_1 c_1 (130°C - 30°C) - m_2 c_2 (30°C - 15°C)}{m_1 - m_2} \]

\[ C = \frac{0.178 \times 4186 \times 15}{0.32 \times 100} = \frac{2}{349} \text{ J/kg°C} \]

3. A 120 grams of ice at temperature 0°C added to water was able to decrease the temperature of water from 26°C to 11°C. What was the mass of the water? (latent heat of fusion for water is 335000 J/kg; specific heat of water is 4186 J/kg°C).

\[ m = \frac{0.120 \times 3.35 \times 10^5 - 0.120 \times 4186 \times (11°C - 0°C)}{4186 \times 15} = 0.73 \text{ kg} \]

4. What is the outside temperature if 22.0 \times 10^6 J of heat is lost through a 4.0 m^2 pane of 3.5 mm thick glass (k = 0.84 W/m°C) in one hour from a house kept at 20°C?

\[ \frac{0 - 20}{12} = \frac{T_1 - T_2}{2} \]

\[ T_1 - T_2 = \frac{22 \times 10^6}{3600 \times 4 \times 0.0035 \times 0.84} = 6.4°C \]

\[ T_2 = 20°C - 6.4°C \]
5. A thermopane window consists of two glass panes, each 0.6 cm thick, with a 1-cm-thick sealed layer of air in between. If inside the room temperature is 23 °C and the outside temperature is 0 °C, determine the rate of energy transfer through 1m² of the window.  \( k=0.84 \text{ J/SmK} \) \( k_{\text{air}}=0.0234 \text{ J/SmK} \)

\[
\text{Ans. } P = 52 \text{ W}
\]

\[
R_1 = \frac{R_3}{0.84} = 0.007 \quad R_2 = \frac{0.01m}{0.0234} \quad R_2 = 0.427
\]

\[
\frac{\dot{Q}}{\dot{E}} = A \frac{T_2 - T_1}{R_1 + R_2 + R_3} = 1m^2 \frac{23^\circ C - 0^\circ C}{2 \times 0.007 + 0.427} = 6.24
\]

6. A radiator has an emissivity of 0.7 and its exposed area is 1.2 m². The temperature of the radiator is 85°C and the surrounding temperature is 20°C. What is the net heat flow rate from the radiator? \( \sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4 \)

\[
\text{Ans. } P = 431 \text{ W}
\]

\[
\frac{\dot{Q}}{\dot{E}} = e \sigma A (T_1^4 - T_2^4) = 0.7 \times 5.67 \times 10^{-8} \times 1.2 \text{ m}^2 (368^4 - 293^4)
\]

7. How much power is radiated by a tungsten sphere (emissivity \( e = 0.35 \)) of radius 22 cm at a temperature of 32°C?
\( P = 105 \text{ W} \)

\[
A = 4\pi R^2 = 4\pi \times 0.22 \text{ m}^2 = 0.61 \text{ m}^2
\]

\[
\frac{\dot{Q}}{\dot{E}} = 0.35 \times 5.67 \times 10^{-8} \times 0.61 \text{ m}^2 \times 308^4
\]

8. How much power is absorbed by a tungsten sphere (emissivity \( e = 0.35 \)) of radius 22 cm if the sphere is enclosed in a room whose walls are kept at -5°C?
\( P = 62 \text{ W} \)

\[
A = 0.61 \text{ m}^2 \quad T = 273 - 5^\circ C = 268^\circ C
\]

\[
\frac{\dot{Q}}{\dot{E}} = 0.35 \times 5.67 \times 10^{-8} \times 0.61 \text{ m}^2 \times 268^4
\]
9. What is the rate of energy absorption from the Sun by a person lying flat on the beach on a clear day if the Sun rays make a 30° angle with the vertical? Assume emissivity 0.7 and area to be 0.8 m².

\[ P = 500 \text{ W} \]

\[ \frac{0.7 \times 0.8 \text{ m}^2 \times 1000 \text{ W/m}^2 \times \cos 30°}{1000 \text{ W/m}^2} = 500 \text{ W} \]

10. A rod, with sides insulated to prevent heat loss, has one end immersed in boiling water at 100°C and the other end in a water-ice mixture at 0°C. The rod has uniform cross-sectional area 7.05 cm² and length 87 cm. The heat conducted by the rod melts the ice at a rate of 1.0 g every 11 seconds. What is the thermal conductivity of the rod? Heat of fusion of water is \(3.34 \times 10^5 \text{ J/kg}\).

\[ \text{Ans } k = 370 \text{ W/m s} \]

\[ m \ell F = k \frac{12 - 11}{2} \times \frac{100}{0.87 \text{ m}} \times 11 \text{ s} \]

\[ 0.001 \times 3.34 \times 10^5 = k \times 7.05 \times 10^{-4} \text{ m}^2 \times 100 \text{ W} \]

\[ k = \frac{334}{0.87 \times 11} = 370 \frac{\text{ W}}{\text{ m s}} \]

11. Gas in a container expands at a constant pressure of 3 atm adiabatically. Find the change in the internal energy of the gas (in J) if the initial volume is 5 liters and the final volume is 10 liters. (1 atm = 1.013x10^5 Pa, 1L = 0.001 m³)

\[ \Delta U = 0 \text{ J} \quad Q = 0 \text{ J} \]

\[ W = p \Delta V = 3 + 1.013 \times 10^5 \left(10 + 10^{-3} - 5 + 10^{-3}\right) \]

\[ = +1500 \text{ J} \]

\[ \Delta U = -1500 \text{ J} \]

12. Calculate the work done by an ideal gas in going from state A to state C for each of the following processes:
(a) ADC, and (b) AC directly. \(P_A = 2.2 \text{ atm}, P_C = 2.7 \text{ atm}, V_A = 3.2 \text{ L} V_C = 4.7 \text{ L}\)

(a) \text{Ans W = 330 J}

\[ W = P_n (V_C - V_A) \]

(b) \text{Ans W = 37.5 J}

\[ W = 2.2 \times 10^5 \times 1.5 \times 10^{-3} \text{ m}^3 \]

\[ W = \frac{1}{2} (V_C - V_A) \times (P_C - P_A) \]
13. A Carnot engine takes 2000 J from a hot reservoir at 500 K, does some work, and discards some heat to a cold reservoir at 350 K. The work done by the engine is closest to

\[ W = eQ_H + W = eQ_H = 0.3 \times 2000 J = 600 J \]

14. A refrigerator has a coefficient of performance of 4.0. When removing \(2.4 \times 10^4\) J from inside the refrigerator, how much energy is sent into the environment?

\[ Q = 3 \times 10^4 J \]

\[ Q_L = 2.4 \times 10^4 J \]

\[ COP = \frac{Q_L}{W} \quad W = \frac{Q_L}{COP} = 60000 J \]

\[ Q_H = Q_L + W = 240000 J + 60000 J \]

15. One kilogram of chilled water at 10° C is placed in a freezer which is kept at -12° C. Approximately how much electric energy is needed to operate the compressor to transform this water into ice at -12° C if the room temperature is maintained at 20° C? \((L_i = 3.33 \times 10^5 \text{ J/kg}; \ c_{ice} = 2090 \text{ J/kg°C}; \ c_w = 4186 \text{ J/kg°C})\)

\[ Q_L = m_L \cdot c_w \cdot (10° C + 20° C) = 50000 J \]

\[ Q_L = 4186 J \cdot 10° C + 3.34 \times 10^5 J + 2050 J \cdot (-12° C) \]

\[ Q_L = 4 \times 10^5 J \]

\[ COP = \frac{T_L}{T_H - T_L} = \frac{273 - 12}{293 - 261} = 8 \]

16. A mass of 0.40 kg, hanging from a spring with a spring constant of 80 N/m, is set into an up-and-down simple harmonic motion. What is the speed of the mass when moving through the equilibrium point? The starting displacement from equilibrium is 0.10 m.

\[ v = 1.4 \text{ m/s} \]

\[ w = \sqrt{\frac{12}{m}} = \sqrt{\frac{80 \text{ N/m}}{0.4 \text{ kg}}} = 14.1 \frac{\text{rad}}{\text{s}} \]

\[ u_m = 0.1 \text{ m} + 14.1 \frac{\text{rad}}{\text{s}} \ rac{\text{rad}}{\text{s}} = 1.4 \text{ m/s} \]
17 A mass of 0.40 kg, hanging from a spring with a spring constant of 80 N/m, is set into an up-and-down simple harmonic motion with an amplitude of 0.1 m. What is the speed of the mass when moving through a point at 0.05 m?

\[ U = \sqrt{\frac{1}{2} k A^2 - \frac{1}{2} k x^2} = \sqrt{80 \times 0.1^2 - 80 \times 0.05^2} \]

\[ \frac{1}{2} k A^2 = \frac{1}{2} m u^2 + \frac{1}{2} k x^2 \]

\[ \text{Ans. } V = 1.2 \text{ m/s} \]

18 A 0.3-kg block, attached to a spring, executes simple harmonic motion according to \( x = 0.08 \cos (35 \text{ rad/s} \cdot t) \), where \( x \) is in meters and \( t \) is in seconds. (a) Find the total energy of the spring-mass system. (b) Find the acceleration of the block at \( t = 4.2 \text{ s} \)

\[ (a) \quad \frac{1}{2} k = \omega^2 m = 35^2 \cdot 0.3 \]

\[ \frac{1}{2} k = 367.5 \text{ N/m} \]

\[ E - \frac{1}{2} k A^2 = \frac{1}{2} k A^0 \times 0.08^2 \]

\[ (b) \quad a = -\omega^2 x = -35^2 \cdot 0.08 \cos (35 \cdot 4.2) \]

19. A 1.5-kg cart attached to an ideal spring with a force constant (spring constant) of 20 N/m oscillates on a horizontal, frictionless track. At time \( t = 0.00 \text{ s} \), the cart is released from rest at position \( x = 10 \text{ cm} \) from the equilibrium point. (a) Write down the equation of motion of the cart. (b) Find the position of the cart and its velocity (magnitude and direction) at \( t = 5.0 \text{ s} \)

\[ \text{Ans. (a) } x = 10 \cos 3.65 t \quad (b) \quad x = 8.25 \text{ cm} \quad v = 0.2 \text{ m/s to the right} \]

\[ \omega = \sqrt{\frac{12}{1.5}} = \sqrt{80/1.5} = 3.65 \text{ rad/s} \]

\[ x = 10 \cos (3.65 \times 5) = 8.25 \text{ cm} \]

\[ U = -10 \cos (3.65 \times 5) = 0.2 \text{ m/s} \]

20. A 12.0-m brass wire is pulled taut with a tension of 125 N. It takes 0.09 s for a wave to propagate along the wire. What is the linear mass of the wire?

\[ \text{Ans. } 0.007 \text{ kg/m} \]

\[ U = \sqrt{\frac{F}{\mu}} \quad U^2 = \frac{F}{\mu} \quad \mu = \frac{F}{U^2} \]

\[ \mu = \frac{125 N}{(U)^2} = \frac{125 N}{(1.33)^2} = 0.007 \frac{1 \text{ kg}}{\text{m}} \]

\[ d = U \cdot t \quad U = \frac{0.09 \text{ m}}{1.33 \text{ m/s}} = 0.068 \text{ s} \]
21. A rope with a total mass of 25.0 kg is tied to a tree on one side of a 125-m wide ravine. You are pulling on the other end of the rope with a force of 415 N. If you pluck the rope at your end, how long will it take the pulse to travel across the ravine to the tree?

Ans. \( t = 2.74 \) s

\[
\sqrt{\frac{T}{\mu}} = \sqrt{\frac{15N}{0.2\text{kg/m}}} = 45.5\text{m/s}
\]

\[
t = \frac{d}{v} = \frac{125\text{m}}{45.5\text{m/s}}
\]

22. Find the fundamental frequency of a standing wave on a string of linear mass 0.004 kg/m and length 0.6 m when it is subjected to tension of 50.0 N is closest to:

93 Hz

\[
f = \frac{v}{2L} = \sqrt{\frac{50N}{0.004\text{kg/m}}} = 112\text{m/s}
\]

\[
f = \frac{112\text{m/s}}{2+0.6\text{m}}
\]

23. A standing wave of frequency 45 Hz is set up on a string 6 m long as shown. What is the speed at which wave propagates on the string?

180 m/s

\[
u = \gamma \cdot f
\]

\[
\gamma = \frac{2L}{n} = \frac{2+6\text{m}}{3} = 4\text{m}
\]

\[
u = 4\text{m} \cdot 45\text{Hz}
\]
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\[ T(0^\circ C) = \frac{5}{9}(T(0^\circ F) - 32); \quad T(0^\circ F) = \frac{9}{5}T(0^\circ C) + 32; \quad \Delta T(0^\circ F) = \frac{9}{5}\Delta T(0^\circ C); \quad T(K) = [T(0^\circ C) + 273] \]

Heat: \( Q = m \cdot c \cdot \Delta T \)  \quad Calorimetry: \( Q_{\text{gained}} = Q_{\text{lost}} \)  \quad Power: \( P = \frac{Q}{t} \)

Heat transfer: \( \frac{Q}{t} = kA \frac{T_1 - T_2}{L} \)  \quad \( \frac{Q}{t} = A \frac{T_1 - T_2}{R_1 + R_2 + R_3} \)

\( \sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4 \)

Thermodynamics:  \( \Delta U = Q - W \)  \quad \( W = p\Delta V \)  \quad \( Q_h = W + Q_c \)  \quad \( e = \frac{W}{Q_h} \)

Oscillations:  \( F = -kx \)  \quad \( x = A\cos(\omega t) \)  \quad \( v = -\omega A\sin(\omega t) \)  \quad \( a = -\omega^2 A \)

\( \omega = 2\pi f \)  \quad \( \omega = \frac{2\pi}{T} \)  \quad Period: \( T_{\text{spring}} = 2\pi\sqrt{\frac{m}{k}} \);  \quad \( T_{\text{pend}} = 2\pi\sqrt{\frac{L}{g}} \)

E = \( \frac{1}{2}mv^2 + \frac{1}{2}kx^2 \);  \quad E = \( \frac{1}{2}kA^2 \);  \quad E = \( \frac{1}{2}m(v_m)^2 \)

waves:  \( v = \lambda \cdot f \)  \quad \( \mu = \frac{m}{L} \)  \quad \( v = \sqrt{\frac{F}{\mu}} \)  \quad \( f = \frac{v}{2L}n \)

\( A_{\text{circle}} = \pi r^2 \)  \quad \( A_{\text{sphere}} = 4\pi r^2 \)  \quad \( A_{\text{cylinder}} = 2\pi r \cdot L \)  \quad \( V_{\text{cube}} = a^3 \)  \quad \( V_{\text{sphere}} = \frac{4}{3}\pi R^3 \)

\( V_{\text{cyl}} = \pi r^2 L \)  \quad \( 1m = 100 \text{ cm} \)  \quad \( 1 \text{ kg} = 1000 \text{ g} \)