Sample: Physics - Physics Midterm

1. At what temperature will the Fahrenheit scale and the Celsius scale show the same reading?

Solution:

The formulas for converting between degree Celsius and degree Fahrenheit are:

°F = (°C * 9/5) + 32

°C = (°F - 32) * 5/9

To find the temperature when both are equal, we just set ºF = ºC and solve one of the equations.

°C = (°C * 9/5) + 32

°C - (°C * 9/5) = 32

-4/5 * °C = 32

°C = -32 * 5/4

°C = -40

°F = (°F * 9/5) + 32

°F - (°F * 9/5) = 32

-4/5 * °F = 32

°F = -32 * 5/4

°F = -40

So the temperature when both the Celsius and Fahrenheit scales show the same reading is -40 degrees.

Answer. -40 degrees.

2. On average, each American produces 20,000 kg of CO_2 per year, mostly through the consumption of fossil fuel such as oil, coal, and natural gas. If you imaging putting this amount of gas into a cube at STP (standard temperature and pressure), what would be the length of each side of the cube?

Solution:

In order to calculate the mass of one mole of carbon dioxide, or CO_2, we need to calculate the molar masses of each of the atoms of this molecule. A molecule of carbon dioxide consists of one carbon atom that is covalently bonded to two oxygen atoms.

Molar mass of O = 15.9994 g/mol

Molar mass of C = 12.0107 g/mol

The molar mass of the molecule of carbon dioxide CO_2 is calculated:

M_{CO2} = 12.011 + 2(16.00) = 12.011 + 32.00 = 44.011 g/mol.

Now we find how many moles of CO_2 we have:

$$n = \frac{20000 \cdot 10^3 \text{ g}}{44.011 \text{ g/mol}} = 45443.2 \text{ mol}$$

1 mole of any gas has a volume of 22.4 L or $22.4 \cdot 10^{-3}$ m^3.

Our amount of CO_2 has a volume

$$V = n \cdot 22.4 \cdot 10^{-3} = 45443.2 \cdot 22.4 \cdot 10^{-3} = 1017.93 \text{ m}^3$$

The length of each side of the cube

$$L = \sqrt[3]{V} = \sqrt[3]{1017.93} = 10.06 \text{ m}$$

Answer. L= 10.06 m.

3. How many kg of lead can you melt using 5000 J of heat, starting at 20°C?

Solution.

Given:

T_0= 20°C,

Q= 5000 J,

a specific heat of c=129 J/(kg K),

and a melting point of T_m = 327.5°C.

(!!! You need to use data from your book !!!)

Heat of fusion is the amount of heat energy required to change the state of a substance from solid to liquid. The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius.

The amount of heat needed to heat lead to melting point:

$$Q_1 = cm(T_m - T_0)$$

The amount of heat needed to melting lead:

$$Q_2 = \Delta H_f \cdot m$$

The given amount of heat

$$Q = Q_1 + Q_2$$

$$Q = cm(T_m - T_0) + \Delta H_f \cdot m$$

$$m = \frac{Q}{c(T_m - T_0) + \Delta H_f}$$

$$m = \frac{5000}{129 \cdot (327.5 - 20) + 23200} = 0.0795 \text{ kg} = 79.5 \text{ g}$$

Answer. m = 79.5 g.

4. A radiator with a constant temperature of 150°C has a surface area of 5.00 m^2. Calculate its rate of heat loss by radiation to the enviroment, which is at constant 20°C. Use value of 0.98 for emissivity.

Solution.

When a hot surface is surrounded by an area which is colder energy in the form of heat will be transferred from the hot surface to the cooler area. The rate of this transfer is depended on the temperature difference and the process will continue until both the surface and the surroundings are at the same temperature.

Heat radiation from a body to the enviroment:

$$\dot{Q}_r = \sigma A_1 e(T_1^4 - T_2^4)$$

$\dot{Q}_r$ is radiated energy (W)

T_1 = 150+273= 423 K (temperature or radiating body)

T_2 = 20+273=293 K (temperature of enviroment)

A_1 = 5.00 m^2 (area of Radiating surface)

e_1= 0.98 (emissivity of Radiating surface)

σ = 5.67·10^{-8} W m^{-2} K^{-4} (Stefan Boltzman constant)

$$\dot{Q}_r = 5.67 \cdot 10^{-8} \cdot 5 \cdot 0.98 \cdot (423^4 - 293^4) = 6847.3 \text{ W}$$

Answer. 6847.3 W.

5. A sinusoidal wave is described by the equation

$$D(x,t) = (12.0\text{ cm})\sin(3.6x - 155t)$$

where x is m and t in seconds. What are the (a) frequency, (b) wavelenght, and (c) speed of the wave?

Solution.

Consider a transverse harmonic wave traveling in the positive x-direction. Harmonic waves are sinusoidal waves. The displacement D of a particle in the medium is given as a function of x and t by

$$D(x,t) = A\sin(kx - \omega t)$$

Here k is the wave number, k = 2π/λ, and ω = 2π/T = 2πf is the angular frequency of the wave, f is the frequency of the wave

The traveling wave is given by $D(x,t) = (12.0\text{ cm})\sin(3.6x - 155t)$

(a) The frequency is found from the coefficient of t.

$$f = \frac{\omega}{2\pi} = \frac{155}{2 \cdot 3.14} = 24.68 \approx 24.7\text{ Hz}$$

(b) The wavelength is found from the coefficient of x.

$$\lambda = \frac{2\pi}{k} = \frac{2 \cdot 3.14}{3.6} = 1.744 \approx 1.7\text{ m}$$

(c) The velocity is the ratio of the coefficients of t and x.

$$v = \frac{\omega}{k} = \frac{155}{3.6} = 43.055 \approx 43.1\text{ m/s}$$

Answer. (a) f = 24.7 Hz; (b) λ = 1.7 m; (c) v = 43.1 m/s.