Fundamentals of Physics in Engineering I

Unit 4.- HEAT AND TEMPERATURE

1.-(a) A carpenter uses a steel measuring tape whose length is 50 m at a temperature of 20ºC. (a) Find the length of the tape at a temperature of 40ºC. (b) The same carpenter uses the tape to measure the width of a wood plank when the temperature is 40ºC and the value measured is 3.5794 m. Obtain the actual width of the plank if the tape is calibrated for using it at 20°C. The coefficient of linear expansion of steel is $\alpha = 1.2 \times 10^{-5}\ K^{-1}$.

2.-A 250-cm^3 glass flask is filled to the brim with mercury at a temperature of 25ºC. Find the amount of mercury that overflows when the temperature of the system is raised up to 100°C. The coefficient of linear expansion of the glass is $0.4 \times 10^{-5}\ K^{-1}$ and the coefficient of volume expansion of the mercury is $18 \times 10^{-5}\ K^{-1}$.

3.-The standard temperature and pressure (STP) is a state of an ideal gas with a temperature of 0ºC = 273.15 K and a pressure of 1 atm = 1.013×10^5 Pa. What would be the volume of a container that contains one mole of an ideal gas in a room at STP?

4.-A mixture of air and vaporized gasoline is compressed inside the cylinders of an automobile engine before being ignited. We know that a typical engine has a compression ratio of 9 to 1, which means that the gas in the engine cylinder is compressed to a final volume, which is 1/9 of its original volume. If the initial pressure and temperature are 1 atm and 27ºC, respectively, and the pressure after compression is 21.7 atm, find the temperature of the compressed gas.

5.-The volume of a tank used for scuba diving is 11 l and the gauge pressure when filled, is 2.10×10^7 Pa. When the tank is "empty", it contains 11 l of air at a temperature of 21 ºC and a pressure of 1 atm ($1{,}013 \times 10^5$ Pa), whereas when the tank is filled with hot air from a compressor, the temperature rises to 42°C and the gauge pressure is still 2.10×10^7 Pa. Determine the mass of air that is added to the tank, knowing that the air is a mixture of gases: approximately 78% nitrogen, 21% oxygen and 1% other gases, and their average molecular mass is 28.8 g / mol.

6.-In the atmosphere, pressure p varies with height y according to the general equation $dp/dy = -\rho g$, where ρ is the density and g the acceleration due to gravity. Find the atmospheric pressure variation with height, assuming that the temperature is 0ºC at all points and ignoring the variation of the acceleration of gravity g with height.

7.-We are designing an electronic circuit element made of 23 mg of silicon whose electrical resistance is R = 1850 Ω, so that electrical current passing through it is I = 2 mA. If the design does not include the removal of heat from the element, how quickly will its temperature increase? The specific heat of silicon is 705 J kg^{-1} K^{-1}.

8.-A Physics student wants to cool 330 g of a low-calorie drink (almost pure water), which is at a temperature of 25ºC, adding ice cubes at -20ºC. Determine the mass of ice that the student must add to the drink to reduce the temperature until 0°C with all the ice melted. Assume the heat capacity of the glass can be neglected. Specific heats: water, 4190 J kg^{-1} K^{-1}, ice, 2100 J kg^{-1} K^{-1}. Ice latent heat of fusion, 334 J/kg.

9.-An engineer, who visits every day a building to check its telecommunications infrastructure, drinks his morning coffee in a 120 g cup of aluminium. Every morning, the cup is initially at a temperature of 20ºC when he pours over 200 g of coffee that is initially at 75°C. Determine the final temperature reached by the coffee and the cup in the thermal equilibrium bearing in mind that the specific heat of aluminium is 910 J kg^{-1} K^{-1} and assuming that coffee has the same specific heat as water, 4190 J kg^{-1} K^{-1}, and that no heat is exchanged with the surroundings.

10.-A cooking pot is made of copper and its mass, including the lid of the pot is 2 kg. The pot is initially at a temperature of 150°C and we pour 100 g of water at 25ºC into it, quickly covering it in avoid any water vapour leak. Determine the final temperature of the pot and its contents and determine the phase (liquid or gas) of water. Assume that no heat is lost to the surroundings. The specific heat of water and copper are 4190 J kg^{-1} K^{-1} and 390 J kg^{-1} K^{-1}, respectively.

11.-A room at 20ºC has a 2 m wide and 2.5 m high glass window, with a thickness of 3 mm. Find the heat lost per minute by conduction through the window, knowing that the outside air temperature is 12ºC and the thermal conductivity of glass is 0.0025 cal $cm^{-1}s^{-1}K^{-1}$.

12.-We use a polystyrene foam box to keep drinks cold. The box, with a total wall area (including the lid) of 0.8 m^2 and a wall thickness is 2 cm, is filled with ice, water and low-calorie soda cans (virtually water) at a temperature of 0°C. Determine the heat flow inside the box if outside temperature is 30 ºC, together with the amount of ice that melts in a day, knowing that the thermal conductivity of polystyrene foam is 0.01 W m^{-1} K^{-1} and the heat of fusion of ice is 3.34 x 10^5 J/kg.

13.-We fabricate a fridge using wood (k_{wood} = 0.0006 cal $cm^{-1}s^{-1}K^{-1}$) with a thickness of 1.75 cm lined inside with cork (k_{cork} = 0.0012 cal $cm^{-1}s^{-1}K^{-1}$), with a thickness of 3 cm. If the temperature on the inner surface of the cork is 0 ºC and on the outer surface of the wood is 12 ºC, what is the temperature at the interface wood-cork?

14.-A steel bar has a length of 10 cm and is butt welded with a copper bar whose length is 20 cm, so the system length is 30 cm. The two bars are perfectly isolated by their sides and have the same transversal square section of 2 cm. The free end of the steel bar is kept at a temperature of 100°C by placing it in contact with water vapour, while the free end of the copper bar is kept at 0°C by placing it in contact with ice. Under these conditions, determine the temperature at the junction of the two bars and the total heat flux knowing that the thermal conductivities of steel and copper are 50.2 $Wm^{-1}K^{-1}$ y 385 $Wm^{-1}K^{-1}$, respectively.

15.-A wall of thickness h is built by placing one above the other, two rectangular plates of thickness h, sections S and S', and conductivities k and k' respectively. If each side of the complete wall is at temperatures T_1 and T_2, respectively, determine, in the steady state, the flow of heat through the wall per unit time, and the equivalent conductivity of the wall.

16.- Human body has a total surface area of approximately 1.2 m^2 being its surface temperature 30ºC. Determine the total rate of radiation energy in the body. In the case that the environment is at 20°C, calculate the net rate of heat loss of the body due to radiation. The emissivity of the human body is very close to unity, irrespective of the skin pigmentation, and the value of the Stefan-Boltzmann constant is σ = 5.67 x 10^{-8} $Wm^{-2}K^{-4}$.

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