VERSION B

See version A for full solutions

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PART I: Multiple choice (24 Marks). Questions 1-6 are worth 4 marks each. Each multiple choice question must be answered by circling your answer.

Question 1 (4 marks) Heat from the Sun reaches Earth because of which type of heat transfer?

a) advection

b) radiation

c) nucleation

d) conduction

e) convection

Question 2 (4 marks) Fluid is moving through a tube as shown in Figure 1. The cross sectional area A_2 is exactly half of the cross sectional area A_1. What statement about the relationship between velocities v_1 and v_2 is correct?

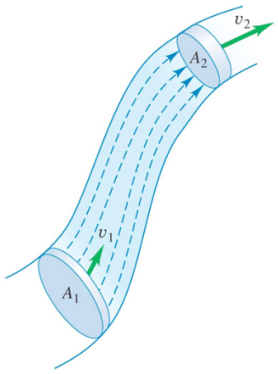

Figure 1: Fluid flowing in tube for Question 2.

a) v_1 is twice the magnitude of v_2.

b) v_1 is half of the magnitude of v_2.

c) v_1 is a quarter of the magnitude of v_2.

d) v_1 is the same as v_2.

e) v_1 is four times the magnitude of v_2.

Question 3 (4 marks) A cylindrical metal rod with length 0.50 m is heated from 25°C to 250°C. If heating the rod increased the length of the rod by 2 cm, by what percentage does the radius of the rod increase?

a) 0%

b) 1%

c) 2%

d) 4%

e) 8%

Question 4 (4 marks) The kinetic molecular model of an ideal gas was constructed using a set of assumptions about how the molecules of the gas and the container they are in behave. Which of the following statements is NOT one of these assumptions?

a) The container walls are perfectly rigid and do not move.

b) The container holding the gas holds a very large number of identical molecules.

c) The molecules behave like point particles that are small compared to the size of the container and the average distance between molecules.

d) The gas molecules exert attractive forces on each other and the container walls.

e) The molecules are in constant motion and undergo perfectly elastic collisions.

Question 5 (4 marks) The density of water changes as a function of temperature. At which of the following temperatures is the density of water at maximum?

a) 100 °C

b) 10 °C

c) 4 °C

d) 0 °C

e) −10 °C

Question 6 (4 marks) What mass of ice can be melted by 2.0×10^6 J of heat? (Some data you may need for this question: Water has a boiling point of 100.0°C, a freezing point of 0.0°C, a heat of vaporization of 2256×10^3 J/kg, a heat of fusion of 333×10^3 J/kg, and a specific heat of 4190 J/kg·K. Ice has a specific heat of 2220 J/kg·K. The molar mass of water is 18.02 g/mol.)

a) 4.5 kg

b) 6.0 kg

c) 0.88 kg

d) 0.66 kg

e) 8.4 kg

PART II: You are required to write full solutions for Questions 7-10. Write your solution in the blank space below each question. If you need more space, please use the back of the page.

Question 7 (20 Marks) How much energy must be removed from 13.34 mol of ethanol that is initially a gas at 78.0 °C so that it becomes a solid at −114.0 °C?

Ethanol has a boiling point of 78.0 °C, a freezing point of −114.0 °C, a latent heat of vaporization of 879 kJ/kg, a latent heat of fusion of 109 kJ/kg, and a specific heat of 2.43 kJ/kg·K. The molar mass of ethanol is 46.07 g/mol.

$m = nM = (13.34\ \text{mol})(46.07\ \text{g/mol}) = 0.615\ \text{kg}$

- CONDENSE GAS -

$Q = -mL_v = -(0.615\ \text{kg})(879\ \text{kJ/kg}) = -540.6\ \text{kJ}$

- COOL LIQUID TO -114°C -

$Q = mc\Delta T$

$= (0.615\ \text{kg})(2.43\ \text{kJ/kg·K})(-192\ \text{K}) = -286.9\ \text{kJ}$

- FREEZE THE LIQUID -

$Q = -mL_f = -(0.615\ \text{kg})(109\ \text{kJ/kg}) = -67.0\ \text{kJ}$

- TOTAL -

$Q_{TOT} = -540.6\ \text{kJ} - 286.9\ \text{kJ} - 67.0\ \text{kJ} = \underline{-894.5\ \text{kJ}}$

Question 8 (20 marks) A block of wood has a mass of 2.95 kg and a density of 600 kg/m^3. It is to be loaded with lead (1.14×10^4 kg/m^3) so that it will float in water with 85% of its volume submerged. The density of water is 1000 kg/m^3.

a) (15 marks) Calculate the mass of lead needed if the lead is attached to the top of the wood.

b) (5 marks) Briefly describe how your calculation would change if the lead was attached to the bottom of the wood.

For 85% submerged with $m_{wood} = 2.95$ kg,

$m_{lead} = 1.23$ kg

Question 9 (12 marks) A steel container with an open top is completely filled with 1.70 m^3 of ethanol. Both the tank and the ethanol are held at 18.0 °C. How much ethanol will spill from the tank if both the tank and its contents are heated to 32.0 °C?

Ethanol has a coefficient of volume expansion of 75×10^{-5} K^{-1}, and the coefficient of volume expansion for steel is 3.6×10^{-5} K^{-1}.

STEEL : $\Delta V_s = V_0 \beta_s \Delta T = (1.70\,m^3)(3.6 \times 10^{-5}\,K^{-1})(14.0\,K)$

$= 8.57 \times 10^{-4}\,m^3$

ETHANOL : $\Delta V_e = V_0 \beta_e \Delta T = (1.70\,m^3)(75 \times 10^{-5}\,K^{-1})(14.0K)$

$= 1.79 \times 10^{-2}\,m^3$

Empty volume in tank : $\Delta V_e - \Delta V_s = 1.79 \times 10^{-2}\,m^3 - 8.57 \times 10^{-4}\,m^3$

$= 1.70 \times 10^{-2}\,m^3$

$= 17.0\,L$

Question 10 (24 marks) (*Note: There is more space to write your solution to this problem on the next page.*) Figure 2 shows a cycle through which 1.00 mol of a monatomic ideal gas is taken. Volume $V_c = 9.00V_b$. Process bc is an adiabatic expansion, with $p_b = 1.013 \times 10^6$ Pa and $V_b = 1.00 \times 10^{-3}$ m^3. For the cycle, calculate

a) (6 marks) the pressure at a, p_a.

b) (5 marks) the energy Q_{ab} added to the gas as heat.

c) (5 marks) the energy Q_{ca} leaving the gas as heat.

d) (4 marks) the net work done by the gas.

e) (4 marks) the efficiency of the cycle.

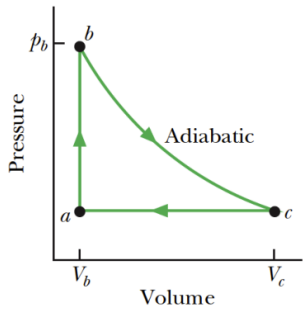

Figure 2: The thermodynamic cycle for Question 10.

a) $p_c = p_b \left(\frac{1}{9}\right)^{1.67} = 2.583 \times 10^4$ Pa

b) $Q_{ab} = \frac{3}{2}\left(p_b V_b - p_a V_a\right) = 1.48 \times 10^3$ J

c) $Q_{ca} = \frac{5}{2} p_a \left(V_a - V_c\right) = -516.6$ J

Extra space for Question 10.

d) $W = Q_{ab} + Q_{ca} = 1480\ \text{J} - 517\ \text{J} = 963\ \text{J}$

e) $e = \dfrac{W}{Q_{in}} = \dfrac{W}{Q_{ab}} = \dfrac{9.63 \times 10^2\ \text{J}}{1.48 \times 10^3\ \text{J}} = 65.1\%$