ESO201A Thermodynamics
Instructor: Jishnu Bhattacharya
Quiz 1
Total points: 40

Date: 4th February 2023
Venue: L19 (S1, S2, S3), L20 (S4, S5, S6)
Allotted time: 50 minutes (9:00 – 9:50 AM)

Important instructions:

You must write your **name**, **roll number** and **section**, and put your **signature** in the space given below.
Be careful, all questions have negative marking.
Please use the space mentioned as "**Rough Work**" in the question paper for calculations, if required.

Name: LAKSHIKA **Signature:**

Roll no.: 210554

Section: G6

QI (10 × 1 = 10 points). Write **True** or **False** for the following statements. +1 point for the correct answer and **-1 point for the wrong answer**. 0 points for the unanswered statement.

#	Statement	True/False
1.	For a control mass, volume remains fixed during a thermodynamic process.	**False**
2.	Sensible energy is the portion of the internal energy of a system associated with the kinetic energies of the molecules.	**True**
3.	Internal energy of a system is a path function that depends on the heat and work interactions with the surroundings.	**False**
4.	Fission reactors emit hazardous gases that pollute the atmosphere and cause global warming.	**False**
5.	Electrical wires carrying current through the boundary of a thermodynamic system is an example of boundary work.	**False**
6.	Efficacy of light sources is a unitless quantity similar to efficiency of a work producing device.	**False**

7.	For a pure substance which expands on freezing, the slope of the fusion line (dP/dT) is negative.	**True**
8.	For a pure substance at a given temperature, if the pressure is lower than the corresponding saturation pressure then the substance is in the superheated vapor state.	**True**
9.	Critical point of a pure substance lies within the liquid-vapour saturation dome	**False**
10.	Cooking takes more time in high altitude places due to lower boiling temperature compared to the sea level.	**True**

QII (10 × 3 = 30 points). Write the correct option **(A, B, C, or D)** for the following questions. +3 points for the correct answer and **-1 point for the wrong answer**. 0 points for the unanswered question.

#	Question	A/B/C/D
1.	A linear Spring whose spring constant is 3.5 kN/cm has an initial force of 0.45 kN acting on it. The work, in kJ, required to compress it by another 1 cm is (A) 0.0022 (B) 0.022 (C) 0.22 (D) 2.2	**B**
2.	A pressure cooker contains saturated water vapor mixture at 100°C with volume of vapor being eight times that of the volume of liquid. The specific volume of saturated liquid and saturated vapor at 100°C are, $v_f = 0.001044$ m^3/kg and $v_g = 1.6729$ m^3/kg, respectively. The quality (x) of the mixture is: (A) 0.005 (B) 0.0006 (C) 0.889 (D) 0.995	**A**
3.	The blood pressure in the upper arm of a healthy person is 120 mm Hg (gage). If a vertical tube open to the atmosphere is connected to the vein in the arm of the person, determine how high the blood will rise in the tube. Take densities of blood and mercury (Hg) to be 1050 kg/m^3 and 13600 kg/m^3, respectively. (A) 0.015 m (B) 0.92 m (C) 1.55 m (D) 1.67 m	**C**
4.	Methane is heated in a rigid container from 80 kPa and 20 °C to 300 °C. If methane can be approximated as an ideal gas, the final pressure (in kPa) is: (A) 35.2 (B) 162.8 (C) 40.9 (D) 156.5	**D**
5.	1 kg of methane is enclosed in a cylinder having volume 6.4 liters and is maintained at a temperature of 13°C and pressure of 18.56 MPa. If molecular weight of methane is 16 kg/kmol and universal gas constant R_u = 8.314 kJ/kmol-K, the compressibility factor Z is: (A) 0.7 (B) 0.8 (C) 0.9 (D) 1.0	**B**
6.	Argon is compressed in a polytropic process with $n = 1.2$ from 120 kPa and 10 °C to 800 kPa in a piston-cylinder device. The work input in the process (in kJ/kg) is the following. For Argon, $R = 0.2081$ kJ/kg.K and $C_v = 0.3122$ kJ/kg.K. (A) 101.4 (B) 109.5 (C) 3.9 (D) 13.6	**B**

7.	At 1 atm pressure, saturation temperature of water is 100 °C. Find out the specific internal energy (in kJ/kg) of a vapour-liquid mixture of water at 100 °C and 1 atm while the total volume and mass of the system are measured to be 5 m^3 and 3.8 kg, respectively. Given: for water at 100 °C, $u_f = 419.06$ kJ/kg; $u_g = 2506$ kJ/kg; $v_f = 0.001043$ m^3/kg; $v_g = 1.672$ m^3/kg. (A) 459 (B) 1254 (C) 2047 (D) 2304	**C**
8.	A pool of water of mass 4.5 kg at 20 °C is to be cooled to 5 °C by dropping ice cubes at 0 °C into it. The latent heat of fusion of ice is 334 kJ/kg and the specific heat of water is 4.18 kJ/kg.K. Assuming heat transfer is limited to ice and water, the amount of ice needed is (A) 795 gm (B) 845 gm (C) 1126 gm (D) 642 gm	**A**
9.	In the Van der Waals equation of state: $(P + a/v^2)(v - b) =$ RT. The constant 'a' represents the effect of: (A) attractive forces between molecules (B) repulsive forces between molecules (C) deviation from molecules being spherical (D) finite size of the molecules	**A**
10.	Choose the correct statement: (A) Carbon dioxide is a poisonous gas (B) Carbon monoxide is a greenhouse gas (C) Both A and B (D) None of A and B	**D**

Name: **Roll no.:**

Rough Work:

1. $W_{spring} = \frac{1}{2}k(x_2^2 - x_1^2)$ Here $k = 3.5$ kN/cm; $kx_1 = 0.45$ kN; Hence, $x_1 = 0.1286$ cm; $x_2 = 1.1286$ cm; Therefore, $W_{Spring} = \frac{1}{2} \times 3.5 \times 10^2 \times (0.011286^2 - 0.001286^2)$ kJ = 0.022 kJ

2. $x = \frac{m_g}{m_f + m_g} = \frac{\frac{V_g}{v_g}}{\frac{V_f}{v_f} + \frac{V_g}{v_g}} = \frac{\frac{8 \times V_f}{1.6729}}{\frac{V_f}{0.001044} + \frac{8 \times V_f}{1.6729}} = 0.005$

3. $P = \rho_{Blood} g h_{Blood} = \rho_{Hg} g h_{Hg}$; $h_{Blood} = \frac{\rho_{Hg}}{\rho_{Blood}} h_{Hg} = \frac{13600\ kg/m^3}{1050\ kg/m^3} \times 0.12\ m = 1.55\ m$

4. $P_2 = \frac{T_2}{T_1} P_1 = \frac{573}{293} \times 80\ kPa = 156.5\ kPa$

5. v = 0.0064 m^3/kg, R = R_u/M = 8.314/16 = 0.52 kJ/kg-K, Z = Pv/RT = 18560 × 0.0064 / [0.52 × (13+273)] = 0.8.

6. $w_{b,out} = \frac{RT_1}{1-n}\left[\left(\frac{P_2}{P_1}\right)^{(n-1)/n} - 1\right] = \frac{0.2081 \times 283}{1-1.2}\left[\left(\frac{800}{120}\right)^{0.2/1.2} - 1\right] = -109.5$ kJ/kg

7. $v = \frac{5}{3.8}$ m^3/kg = 1.316 m^3/kg; $x = \frac{v - v_f}{v_g - v_f} = \frac{1.316 - 0.001043}{1.672 - 0.001043} = 0.78$; $u = u_f + x(u_g - u_f) = 419.06 + 0.78 \times (2506 - 419.06) = 2046.9$ kJ/kg

8. $m_{water} \Delta T_{water} C_P^{water} = m_{ice} Heat_{fusion} + m_{ice} \Delta T_{ice} C_P^{water}$;

$$4.5 \times (20 - 5) \times 4.18 = m \times 334 + m \times 5 \times 4.18$$

$m = 795$ gm

9. Van der Waals equation of state includes two effects not considered in the ideal-gas model: the *intermolecular attraction forces (a/v^2 term)* and the *volume occupied by the molecules themselves (b term).*

10. CO_2 is a greenhouse gas while CO is a poisonous gas.