Student Name:

Question 1 (20 points)

Select the most correct answer and circle it in the provided answers sheet. More than one answer may be correct, make your choices carefully and wisely.

1. A liquid at a temperature **above** its saturation temperature is called
   a) subcooled b) supercooled c) subcritical d) metastable
2. An adiabatic and reversible process is
   a) Isothermal b) Isenthalpic c) Isentropic. d) Isobaric
3. A polytropic process with an exponent $n = 1$ can alternatively be called
   a) Isothermal b) Isobaric c) Isochoric d) Adiabatic
4. The value of the specific heat at constant volume of nitrogen assuming it to be an ideal gas
   a) 1.5R b) 2.5R c) 3.5R d) 4.5R
5. The entropy change for a reversible process in accordance with the second law
   a) $\Delta S_{\text{System}} \geq 0$ b) $\Delta S_{\text{Surroundings}} \geq 0$ c) $\Delta S_{\text{Universe}} \geq 0$ d) $\Delta S_{\text{Universe}} = 0$
6. The reading of a vacuum gauge pressure in a steam jet ejector is reported as 0.1 atm, then the absolute pressure in atmospheres is
   a) 0.1 b) 0.9 c) 1.1 d) -0.1
7. A Joule-Thomson expansion is also
   a) Isothermal b) Isobaric c) Isentropic d) Isenthalpic
8. The triple point temperature for water is
   a) 0.01 K b) 273.16 K c) 273.15 K d) 273.00 K
9. The Clausius-Clapeyron is valid for which transitions?
   a) Solid-Liquid b) Solid-Vapor c) Liquid-vapor d) b & c
10. If the Mach number of the shockwave accompanying a mechanical explosion is less than one; then the shockwave is classified as?
   a) Supersonic b) Sonic c) Subsonic d) Ultrasonic

	(A)	(B)	(C)	(D)
01	○	○	○	●
02	○	○	●	○
03	●	○	○	○
04	○	●	○	○
05	○	○	○	●
06	○	●	○	○
07	○	○	○	●
08	○	●	○	○
09	○	○	○	●
10	○	○	●	○

Fill the circles completely.
Don't fill more than one circle for each question. If there are more than one circles filled, you will get a zero for that question.
No answers on the questions sheet will be accepted.
Use a black/blue pen not a pencil.

Question 2 (20 points)

A well insulated tank contains 1000 kg of a reaction mixture with a specific heat equivalent to that of water. The mixture needs to be stirred for a period of **one hour** using an impeller. The shaft takes it power from an electric motor operating at 220 volts and 5 amperes current with an overall efficiency of 85%.

1. How much power is available at the shaft?
2. How much heat must be removed from the motor per hour?
3. What is the temperature rise of the reaction mixture due to stirring?

Solution

First law analysis for the motor at steady state

$$0 = Q + W_{\text{electric}} + W_{\text{Shaft}} \Rightarrow Q = -(W_{\text{electric}} + W_{\text{Shaft}})$$

$$W_{\text{electric}} = EI\Delta t = (5)(220)(3600) = 3960000 \text{ J}$$

$$W_{\text{Shaft}} = -0.85 W_{\text{electric}} = -(0.85)(3960000) = -3.366 \times 10^6 \text{ J}$$

$$Q = -(3960000 - 3.366 \times 10^6) = -5.94 \times 10^5 \text{ J.}$$

First law analysis for the tank

$$\Delta U = W_{\text{Shaft}}$$

$$mc_v \Delta T \simeq mc_P \Delta T = W_{\text{Shaft}}$$

$$(1000 \text{ kg})(4184 \text{ J/kg.K})\Delta T = 3.366 \times 10^6 \Rightarrow \Delta T = 0.8 \text{ K.}$$

Comment. This is a very small temperature rise which indeed supports the frequently used assumption of the tank being isothermal.

Question 3 (20 points)

A certain ideal gas is compressed reversibly from 1 bar and 17˚C to a pressure of 5 bars in an insulated cylinder the final temperature being 77˚C. The work done on the gas during compression is 45 kJ/kg.

1. What is γ for this gas?
2. What is C_v for this gas?
3. Determine the molar mass for this gas.

Solution

Use the equations for an adiabatic process

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{\gamma-1}{\gamma} = \frac{\ln(350/290)}{\ln(5/1)} = 0.11684 \Rightarrow \gamma = 1.132$$

From the definition of γ for an ideal gas

$$\gamma = \frac{c_P}{c_v} = \frac{c_v + R}{c_v} = 1 + \frac{R}{c_v}$$

$$c_v = \frac{R}{\gamma - 1} = \frac{8.314}{0.132} = 62.985 \text{ J/mol.K}$$

From the first law we have

$$\Delta U = c_v(T_2 - T_1) = W$$

$$c_v(T_2 - T_1) = M(W \text{ kJ/kg})$$

$$M = \frac{c_v(T_2 - T_1)}{(W \text{ kJ/kg})} = \frac{62.985(350 - 290)}{45} = 83.98 \text{ g/mol (kg/kmol)}.$$

Question 4 (20 points)

A cyclic process is carried in five (6) steps on a closed system composed of one mole of an ideal gas. The following table has some missing values. Fill in the missing values (clearly show the calculations you made and sketch the cycle). Also, fill in the step type in the provided column e.g., isothermal, isobaric, adiabatic …etc.

	ΔU (J)	Q (J)	W(J)	Step type
12	0	(-1000) ?	1000	Isothermal
23	2000	0	(2000)?	Adiabatic
34	(-1000)?	-1000	(0)?	Isochoric
45	-1000	(3000)?	-4000	Polytropic
123451	(0)?	1000	(-1000)?	Cycle

Question 5 (20 points)

The vapor pressure for water can be expressed as:

$$\ln P^{\text{vap}}(\text{Pa}) = 26.3026 - \frac{5432.8}{T(\text{K})}$$

1. Compute the boiling point temperature at the University of Jordan where the atmospheric pressure is 680 mm Hg.
2. What is the latent heat of vaporization at the temperature computed in the first part? Compare with the value from the steam tables.

The 680 mm Hg is converted into 90659.2 Pa then by direct substitution into the vapor pressure equation, the normal boiling point at the University of Jordan is found to be 364.9 K. Take the derivative of the vapor pressure equation w.r.t. T to yield

$$\frac{d \ln P^{\text{vap}}}{dT} = \frac{\Delta H^{\text{vap}}}{RT^2} = \frac{5432.8}{T^2}$$

$$\Delta H^{\text{vap}} = (8.314)(5432.8) = 45168\ J/mol$$

$$\Delta H^{\text{vap}} = (45.168\ \text{k}J/mol)/(0.018\ \text{kg/mol}) = 2509.3\ \text{kJ/kg}.$$

The values in steam tables at the same temperature are about 370 K and 2266 kJ/kg. The temperature difference is not that far. However, the latent heat of vaporization is off by about 10%. This may be attributed to the fact that the equation assumes that the latent heat of vaporization is constant while the steam tables does not suffer from such shortcoming. Also, the normal boiling point decreased from the typical value due to the elevation of the University of Jordan location from that of the standard atmosphere at sea level.