UNIVERSITY OF JORDAN
CHEMICAL ENGINEERING DEPARTMENT

905322 – CHEMICAL ENGINEERING THERMODYNAMICS 1

الأسم	:
الرقم الجامعي	:
المادة	: ديناميكا حرارية ١ (٩٠٥٣٢٢)
الامتحان	: الأول
التاريخ	:٢٠\١١\٢٠٠٤
مدرس المادة	: د. علي مطر

السؤال	العلامة الكاملة	العلامة
١	37.5	
٢	30.0	
٣	20.0	
٤	12.5	
٥	X	X
٦	X	X
المجموع	١٠٠	

وقع على القسَم التالي المتعلق بالغش الأكاديمي:

اقسم بالله أنني لم اغش في هذا الامتحان ولم أساعد أي شخص على الغش سواءً لمنفعتي الشخصية أو لمنفعة الآخرين، وعلى هذا أوقع.

التوقيع:

Student Name:

	(A)	(B)	(C)	(D)
01	○	○	●	○
02	○	○	○	●
03	○	○	●	○
04	●	○	○	○
05	●	○	○	○
06	○	●	○	○
07	○	●	○	○
08	○	○	○	●
09	○	○	●	○
10	○	○	●	○
11	○	○	○	●
12	○	○	●	○
13	○	○	○	●
14	○	●	○	○
15	○	○	○	●
16	○	○	○	●
17	○	○	●	○
18	○	○	○	●
19	●	○	○	○
20	○	○	●	○
21	○	●	○	○
22	○	○	○	●
23	○	●	○	○
24	○	○	●	○
25	○	●	○	○

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 1 (37.5 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 Joule-Thompson expansion is

a) Isentropic	b) Isochoric	c) Isenthalpic	d) Isobaric

2. Usually, a jet fighter operates at Mach numbers

a) $\mathbf{M} < 0$	b) $\mathbf{M} < 1$	c) $0 < \mathbf{M} < 1$	d) $\mathbf{M} > 1$

3. The phase change from a vapor to a liquid is called

a) Vaporization	b) Evaporation	c) Condensation	d) a & b

4. The value of vapor pressure above the critical point is

a) None existent	b) 0 atm	c) 1 atm	d) infinity

5. The value of the latent heat of vaporization at the critical point is

a) zero	b) Same as triple point value	c) Same as boiling point value	d) infinity

6. An ideal gas undergoing a throttling process from (300 K, 100 bar) to a final pressure of 1 bar. What is the final temperature of the gas stream exiting from the process?

a) 250 K	b) 300 K	c) 350 K	d) 400 K

7. The outlet stream of a turbine is called

a) Driving fluid	b) Exhaust	c) Suction	d) Discharge

8. An isentropic process is equivalent to

a) reversible isothermal process	b) irreversible isothermal process	c) irreversible adiabatic process	d) reversible adiabatic process

9. The actual work extracted from a turbine is always

a) Equal to the isentropic work	b) Higher than the isentropic work	c) Lower than the isentropic work	d) Equivalent to 100% efficiency

10. A compressor takes a stream at 1 bar and compresses it to 81 bars. How many stages are required to achieve this compression assuming a compression ratio of 3 per stage?

a) 2	b) 3	c) 4	d) 5

11. The device used to increase the velocity of a fluid stream at the expense of pressure is the

a) Diffuser	b) Nozzle	c) Converging section	d) b & c

12. The location in a converging-diverging section at which the velocity becomes sonic is the

a) Slit	b) Neck	c) Throat	d) Mouth

13. In a converging-diverging section, the value of the pressure ratio at which the velocity becomes sonic is

a) $P_2/P_1 < 0$	b) $P_2/P_1 > 0$	c) $P_2/P_1 = 0$	d) $0 < P_2/P_1 < 1$

14. Which one of these quantities is not conserved?

a) Mass	b) Entropy	c) Energy	d) a & c

15. What is the range of typical efficiencies for turbines and compressors?

a) 0.4 – 0.5	b) 0.5 – 0.6	c) 0.6 – 0.7	d) 0.7 – 0.8

16. The device used to move large flow rates of gases at low pressure ratio is called

a) Fan	b) Blower	c) Compressor	d) a & b

17. Differential balances are related to

a) Changes in an interval of time	b) Changes between two moments of time	c) Instantaneous rates	d) None of these

18. The boundaries of the system can be moved by

a) Expansion	b) Contraction	c) System movement	d) All of these

19. Heat can be supplied to or removed from a system by using

a) Jackets and Coils	b) Stirring	c) Direct mixing	d) a & c

20. Water falls in a certain area in Ma'in – Jordan flows at a rate of 1.0 m^3/s and the elevation difference is 10 m. If a turbine was to be installed there to generate electricity, what is the theoretical power that can be extracted from this water fall?

a) 98 MW	b) -98 MW	c) -98 kW	d) 98 kW

21. The RHS of the first law of thermodynamics is a collection of terms that take place

a) Within the system boundaries	b) Across system boundaries	c) Within and across system boundaries	d) None of these

22. Heat and work are

a) Energy in transit	b) Path functions	c) State functions	d) a & b

23. A 0.1 atm vacuum pressure is equivalent to an absolute pressure of

a) 1.1 atm	b) 0.9 atm	c) 1.0 atm	d) -0.1 atm

24. The temperature measuring device used to measure very low temperatures is

a) Thermocouple	b) Pyrometer	c) Cryometer	d) a & b

25. When the number of degrees of freedom is zero; the system is called

a) Variant	b) Invariant	c) Triple point	d) Three phased

Question 2 (30 points)

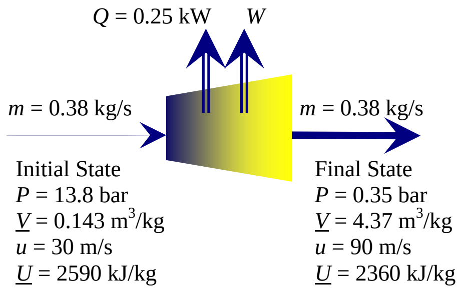
A turbine operating under steady flow conditions receives steam at the following state: pressure 13.8 bar, specific volume 0.143 m^3/kg, specific internal energy 2590 kJ/kg, velocity 30 m/s. The state of the stream leaving the turbine is as follows: pressure 0.35 bar, specific volume 4.37 m^3/kg, specific internal energy 2360 kJ/kg, velocity 90 m/s. Heat is rejected to the surroundings at the rate of 0.25 kW and the rate of steam flow through the turbine is 0.38 kg/s.

1. Calculate the power developed by the turbine.
2. What is the efficiency for this turbine?
3. Comment on the contributions of the various terms.

Assumptions

Open system
Steady-state conditions
For ideal work an isentropic case (adiabatic reversible) process
Negligible PE
Steam tables are applicable for the properties

Sketch



Calculations & Comments

1. The first law subject to the assumptions listed above reduces to

$$0 = -m\frac{(u_2^2 - u_1^2)}{2} - m(\hat{H}_2 - \hat{H}_1) + Q + W$$

   a. Calculate change in KE per unit mass as

$$\Delta KE = \frac{(u_2^2 - u_1^2)}{2}$$

$$= \frac{(90^2 - 30^2)}{2} = 3600 \text{ J/kg.}$$

   b. Calculate change in the enthalpy remembering that $H = U + PV$.

      i. internal energy

$$\Delta U = (\hat{U}_2 - \hat{U}_1)$$

$$= (2360 - 2590)\times 10^3 = -230\times 10^3 \text{ J/kg.}$$

      ii. PV term

$$\Delta(P\hat{V}) = (P_2\hat{V}_2 - P_1\hat{V}_1)$$

$$= \frac{10^5}{10^3}(0.35\cdot 4.37 - 13.8\cdot 0.143) = -44390 \text{ J/kg.}$$

      iii. Enthalpy change

$$\Delta\hat{H} = \Delta\hat{U} + \Delta(P\hat{V})$$

$$= -230,000 - 44,390 = -274,390 \text{ J/kg.}$$

   c. Calculate the sum of power output from the turbine

$$W + Q = m\frac{(u_2^2 - u_1^2)}{2} + m(\hat{H}_2 - \hat{H}_1) = -270,790 \text{ J/kg}$$

$$W = (0.38)(-270,790) + 250 = -102,650 \text{ J/s} = \text{-102.7 kW.}$$

2. The efficiency of the turbine is the ratio of actual power to ideal (isentropic power) which is the enthalpy change. Therefore,

$$\eta = \frac{W}{W_S} = \frac{-102,650}{(0.38)(-274390)} = 0.9845 = 98.45\%$$

3. Clearly, this turbine is very close to being isentropic i.e., the contribution due to KE and heat loss does not amount to more than 1.5% of the ideal turbine work.

Being organized for the solution of such problems can save you precious time during the exam. Tabulate such problems in a table containing all contributions in the initial state, final state, and the change between these two states.

Operating Conditions			
	Initial	Final	Change
T (K)	?	?	Decrease
P(bar)	13.8	0.35	Decrease
$\underline{V}$ (m^3/kg)	0.143	4.37	Increase
u (m/s)	30	90	Increase
m (kg/s)	0.38	0.38	Steady-State
Contributions to energy balance			
	Initial	Final	Change
PE (J/kg)			0
KE (J/kg)			3600
$P\underline{V}$ (J/kg)			-44,390
$\underline{U}$ (J/kg)	2590×10^3	2360×10^3	-230,000
$\underline{H}$ (J/kg)			-274,390
Q (J/kg)			250 (W)
W (J/kg)			-102.7 (kW)
η (%)			98.45

Question 3 (20 points)

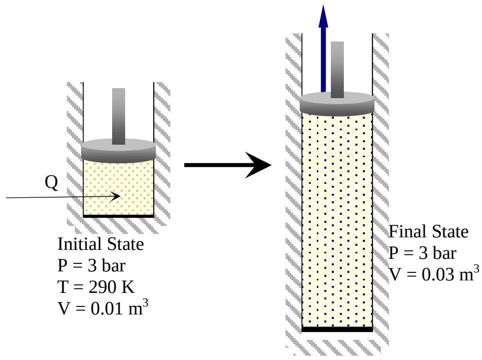
Oxygen (molar mass 32 kg/kmol) expands reversibly in a cylinder behind a piston at a constant pressure of 3 bar. The volume initially is 0.01 m^3 and finally is 0.03 m^3. The initial temperature is 17°C. Assume oxygen to be an ideal gas and take C_P = 0.917 kJ/kg.K.

1. Calculate the work and state its direction.
2. Calculate the heat supplied during the expansion and state its direction.
3. What is the final temperature of the oxygen?

Assumptions

Oxygen is an ideal gas
Closed system
No shaft work
Negligible PE and KE
Reversible process

Sketch



Calculations & Comments

1. The cylinder expands which means that the system is doing work. Therefore, we expect to have a minus sign. The work occurs at isobaric conditions. Consequently, it is given by:

$$W = P(\overline{V}_2 - \overline{V}_1)$$
$$= (3\times10^5)(0.01-0.03) = \ \text{-}6000\ J.$$

2. The heat is being supplied to the system which means that the system is gaining energy. Therefore, we expect to have a positive sign. For a closed system at isobaric conditions

   a. obtain the final temperature of oxygen in the cylinder from the ideal gas law

$$T_2 = T_1 \cdot \frac{V_2}{V_1}$$
$$= 290 \cdot \frac{0.03}{0.01} = 870 \text{ K}$$

   b. calculate the mass of oxygen in the cylinder from the ideal gas law

$$m = \frac{M_{\text{Oxygen}} PV}{RT_1}$$
$$= \frac{(32)(3\times10^5)(0.01)}{(8314)(290)} = 0.0398 \text{ kg}$$

   c. calculate the heat supplied from the enthalpy of an ideal gas

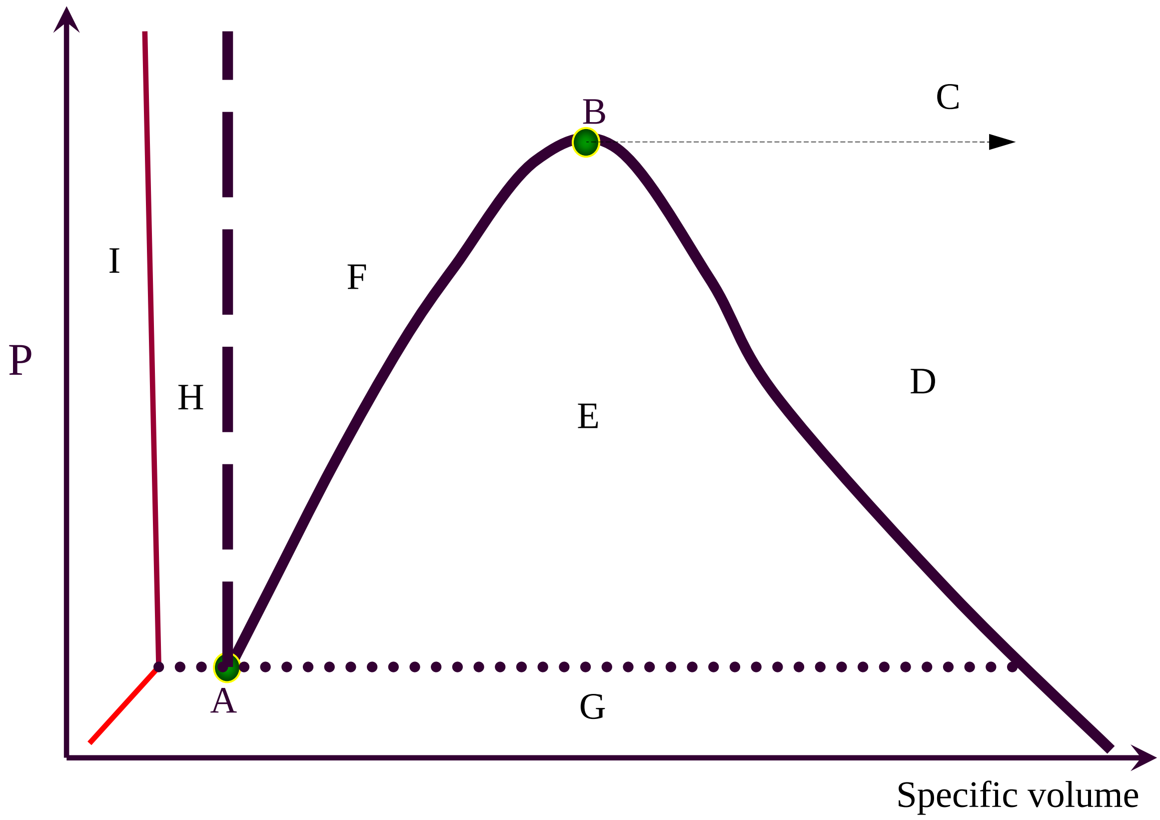
$$Q = mC_P(T_2 - T_1)$$
$$= (0.0398)(0.917)(870 - 290) = 21180 \text{ J.}$$

3. From the last part the final temperature is 870 K.

Operating Conditions			
	Initial	Final	Change
T (K)	290	870	Increase
P(bar)	3	3	–
V (m^3)	0.01	0.03	Expansion
m (kg)	0.0398	0.0398	Closed system
Contributions to energy balance			
	Initial	Final	Change
ΔH (J)			21,180
Q (J)			21,180
W (J)			-6,000

Question 4 (13 points)

Fill the table below for each of the regions labeled with a letter. State the name of the point (region) and the number and name of phase(s) existing in them. Use S for Solid, L for Liquid, V for Vapor, and SC for Supercritical fluids.



Area (point)	Name	Phase(s)	Marks
A	**Triple point**	**3 Phases (S, L, V)**	**2**
B	**Critical point**	**1 Phase (Fluid)**	**1**
C	**Fluid region**	**1 Phase (SC: Supercritical fluid)**	**1**
D	**Vapor region**	**1 Phase (V: Vapor)**	**1**
E	**V-L coexistence region**	**2 Phase (V + L)**	**2**
F	**Liquid region**	**1 Phase (L)**	**1**
G	**Solid-Vapor Region**	**2 Phase (S + V)**	**2**
H	**S-L Region**	**2 Phase (S + L)**	**2**
I	**Solid Region**	**1 Phase (S)**	**1**