Tanta University
Second Term Exam
Time Allowed: 3hrs

Hydraulic and Pneumatic Circuits
Course Code: MEP4229
Total Assessment Marks: 90
4th Year Mechanical Power Engineering

Faculty of Engineering
Mech. Power Eng. Dept
June 1, 2023

Please, answer the following questions:

Question (1) (30Marks)

1. Discuss with the help of free sketch the working principle of oscillatory vane motor.

2. What is the purpose of cushion devices in hydraulic cylinders? Discuss the principle of operation.

3. A pump delivers oil at a rate of 1.15L/s into the blank end of the 76.2mm diameter hydraulic cylinder. The piston contains a 25.4mm diameter cushion plunger that is 19.05mm long. The cylinder drives a 6672N weight which slides on a flat horizontal surface having a coefficient of friction (μ) equal to 0.12, see Fig. 1. The pressure relief valve setting equals 51.7bar. Find the maximum pressure developed by the cushion.

Question (2) (30Marks)

1. What is the purpose of a pressure relief valve? What are its types? Discuss the working principle of the simple type. Illustrate your answer with the help of free sketch drawing and the valve P-Q curve.

2. Discuss with the help of free sketch the working principle of the pressure reducing valve. Mention an example of its function in hydraulic systems.

3. The system shown in Fig. 2 has a hydraulic cylinder with a suspended load W. The cylinder piston and rod diameters are 50.8mm and 25.4mm, respectively. The pressure-relief valve setting is 5150kPa. Determine the pressure P_2 for a constant cylinder extension speed when:
   a) $W = 8890$ N
   b) $W = 0$ (load is removed)
   c) Determine the cylinder extension speeds for parts (a) and (b) if the flow-control valve has a capacity coefficient of 0.72LPM/$\sqrt{\text{kPa}}$. The fluid is hydraulic oil with a specific gravity of 0.90.

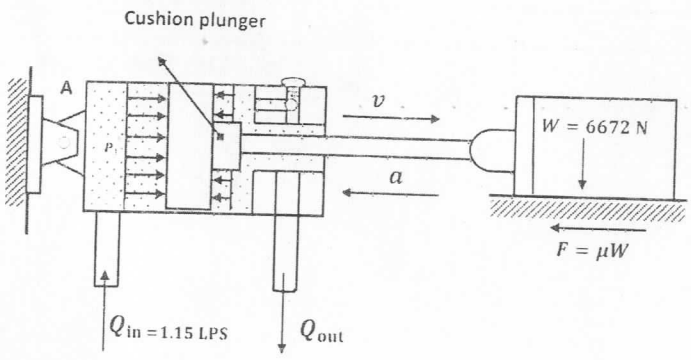


Fig. 1 Cylinder with cushioning device

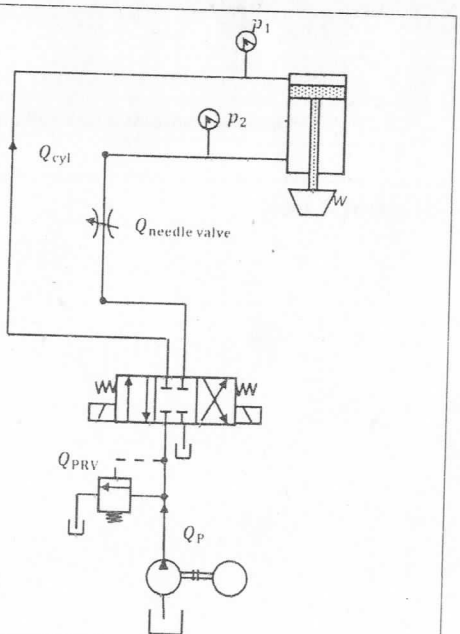


Fig. 2 Circuit for question (2_3)

Question (3) **(30Marks)**

1. For the double pump system shown in Fig. 3 for the application of a sheet metal punch press, what should be the pressure settings of the unloading valve and pressure relief valve under the following conditions:
   - Sheet metal punching operation requires a force of 2000lb.
   - Hydraulic cylinder has a 1.5-in piston diameter and 0.5-in rod diameter.
   - During rapid extension of the cylinder, a frictional pressure loss of 100psi occurs in the line from the high flow pump to the blank end of the cylinder. During the same time a 50psi pressure loss occurs in the return line from the rod end of the cylinder to the oil tank. Frictional pressure losses in these lines are negligible small during the punching operation.

Assume the unloading valve and pressure relief valve pressure settings (for their full pump flow requirements) should be 50% higher than the pressure required to overcome frictional pressure losses and the cylinder punching load, respectively.

4. Figure 4 is a diagram for a circuit of loaded hydraulic cylinder that uses compound relief valve (marked with dash line).
   a) How would the cylinder be extended? re-draw the circuit in this condition.
   b) What is the advantage of using compound relief valve over the simple one?
   c) Given the main spring setting 20psi and the pilot spring setting 1980psi. What will be the setting pressure of the compound relief valve in both conditions: cylinder block and cylinder extension?

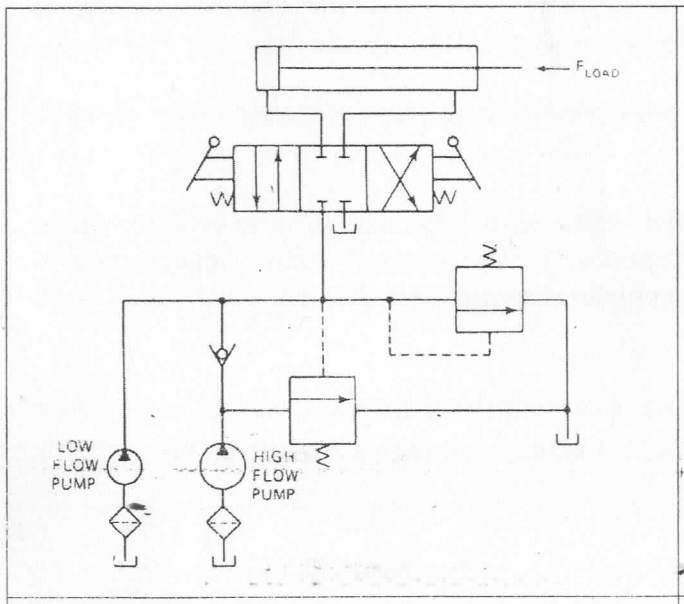


Fig. 3 Double pump system for question (3_1)

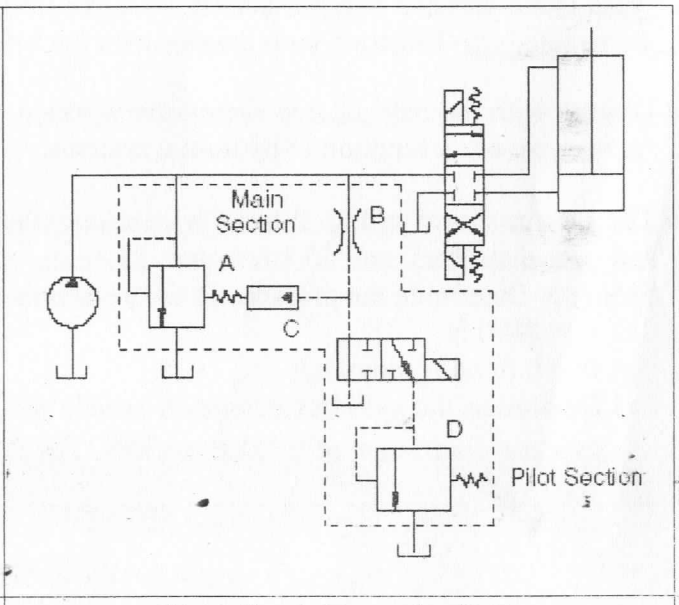


Fig. 4 Circuit for question (3_2)

Best of Luck *Dr. Omar Mehrez*

اسم المقرر	منشآت الطاقة	امتحان دور يوليو للعام الجامعي ٢٠٢٣/٢٠٢٢	كود المقرر	MEP4230
			الفرقة	الرابعة
زمن الامتحان	٣ ساعات	عدد صفحات الامتحان (٢)	تاريخ الامتحان	2023/06/18م
الاجابه بترتيب الأسئلة.			درجه الامتحان: ٨٥ درجه	

السؤال الاول:

ا- عرف مع ذكر أنواع ومميزات وعيوب كل من:

الطاقة المتجددة – الطاقة الغير متجددة.

ب- ماهي محطات الطاقة، وانواعها؟

ج- ما هي انواع الغلايات، مع شرح المكونات الرئيسية لها.

السؤال الثانى:

ا- ما هي المحطات الحرارية وتصنيفها؟

ب- عرف كلا من: محطات الطاقة المائية – محطات الطاقة الشمسية.

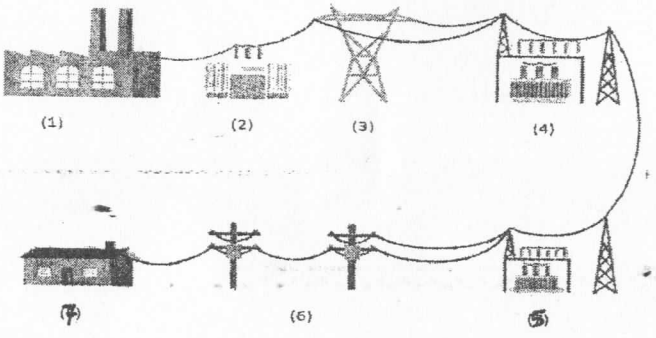
ج- مكونات شبكة توزيع الكهرباء الاساسية والثانوية

السؤال الثالث:

ا- الشكل يوضح مراحل نقل الكهرباء من محطة التوليد حتى المنزل.

اذكر المراحل الموضحة بالأرقام بالترتيب.

ب- ما هو الفرق بين النقل والتوزيع؟



السؤال الرابع:

ضع علامة صح او خطا:

١. تعتبر الطاقة المتجددة صديقة للبيئة، إذ إنها لا تُحرق كالوقود الأحفوري. ( )

٢. من أهم سلبيات هذا الطاقة المتجددة أن التكاليف الأولية لإنشاء محطات الطاقة تكون عالية جدًا وتحتاج تخطيط دقيق. ( )

٣. خلايا الفوتوفولتيك هي خلايا مصنوعة من عنصر الصوديوم، وتقوم بتحويل الأشعّة الشّمسية الساقطة إلى طاقة كهربائيّة بشكل مباشر. ( )

٤. بلغت القدرة الفعلية لمحطة عتاقة البخارية حوالي ٦٠ م. وات عام ٢٠١٩. ( )

٥. تتميز الكابلات الارضية عن الخطوط الهوائية من حيث العمرالافتراضى لها الذي يبلغ حوالي ٢٠-٢٥ عاما. ( )

السؤال الخامس:

أ) اختر مما بين الاقواس:

١. يتم فيها تحويل طاقة الوضع التي تختزنها المياه في المناطق المرتفعة كأعالي السدود والشلالات إلى طاقة حركية لتدير توربين مائي والذي بدوره يدير المولد الكهربي.

(محطات الطاقة الشمسية - محطات الطاقة المائية - المحطات الحرارية)

٢. تعتمد الكفاءة علي:

(مستوي توليد الطاقة - تكلفة الوقود- تكلفة التشغيل)

٣. تصل طاقة المشروعات الحكومية القائمة المتمثلة في الغردقة - الزعفرانة - جبل الزيت الى حوالي

(٦٠٠ميجاوات -٧٥٠ ميجاوات – ٩٠٠ ميجاوات)

٤. من أنواع لخطوط النقل والتوزيع:

(Underground Cables -Over Head Transmission Lines- كلاهما)

٥. تتميز الخطوط الهوائية عن الكابلات الارضية من حيث:

(الامان – احتمال الاعطال – التكلفة)

ب) قارن بين كل من Jet and Surface Condenser.

Best wishes
Dr. M.I.Elhadary

انتهت الاسئلة .....

2/2

لجنة الممتحنين: د./ محمد إبراهيم الحضري

	Tanta University **Faculty of Engineering** **Mech., Power Engineering Dept.** **4th Year Power Mechanics,** **2nd Term**	**Course: Hydraulic Machines (B)** **Code: MEP 4121** **Final Exam, Full Marks: 75.0 marks** **Time allowed: 3.0 hrs No of pages: 2.0** **Date: 12-06-2023**

Question (1) (18 Marks)

1. Derive a relations for calculating: **(5.0 Marks)**

(a) The inertia heads of the suction and delivery pipes of the piston pump.

(b) The frictional heads of the suction and delivery pipes of the piston

(c) Then clearly **drawing** the actual indicator diagram of the piston pump.

2. In a double acting piston pump with a piston diameter of 12 cm and stroke of 18 cm running at 60 rpm. An air vessel is fixed at the delivery side at a distance of 3 m from the level of the pump. The length and diameter of the delivery pipe are 25 m and 10 cm, respectively. The atmospheric pressure head is 10.3 m and the separation occurs at pressure head of 2.5 m. Assume $f = 0.04$, **Calculate:**

(a) The reduction percentage in the delivery inertia head due to the fitting of the air vessel.

(b) The reduction percentage in the delivery frictional head due to the fitting of the air vessel.

(c) Maximum speed of the pump **(9.0 Marks)**

3. Define the following expressions:

(a) Spillway (b) Deflector plate **(4.0 Marks)**

(c) Buttressed dams (d) Reaction turbine

Question (2) (20 Marks)

1. ***Prove that*** the percentage of frictional work done saved by air vessel for double acting piston pump is 39.20 % **(5.0 Marks)**

2. A single acting piston pump is used drain an excavation. The pump has diameter 150 mm and a stroke 400 mm. The suction and delivery pipes are both 50 mm in diameter, the suction pipe being 2 m long while the delivery pipe 15 m long. The suction lift to the pump is 1.5 m and the delivery is 6 m above the suction level. In the absence of any air vessels on either pump suction or delivery, **Determine:** **(8.0 Marks)**

(a) The absolute pressure head in the piston cylinder at: (1) Start (2) End, (3) Middle of each stroke if the pump speed is 0.20 rev/s. Assume the pump slip factor of 4% and $f = 0.04$.

(b) The maximum pump speed if the atmospheric head is 10.3 m and fluid vapour pressure is 2.4 m

(c) The increase of pump speed in rev/min if a large air vessel is fitted closed to the suction valve

3. What is the concept of a dam with a detailed drawing of a section of a dam showing its components and technical form in terms of upstream and downstream? **(4.0 Marks)**

4. Draw a detailed schematic diagram of the hydraulic electrical power plant showing its components and technical form, and then define briefly the function of each component. **(3.0 Marks)**

Question (3) (20 Marks)

a) Fll in the blank wih a suitable words **(8 Marks)**

1- In Kaplan turbine the roto blades can be .....to suit the load.
2- the specific speed is lowest in the case of .....turbine.
3- Axial thurst is minimal in the case of.....turbine.
4- Spiral casing is used in the case of.....and.....turbine.
5- A jet deflector is used in Pelton turbine when the load .....
6- Govering of hydraulic turbines is by varying.....
7- Sudden cutting off the water flow will cause .....in the penstock.
8- Cavitation could only happen in .....turbines.

b) Drive an equation for maximum hydraulic efficiency of a Pelton wheel turbine. **(4 Marks)**

c) Explain briefly, aided with appropriate drawing, why a neddle valve is recommended for controlling the load of Pelton wheel turbine over throttle valve. **(3 Marks)**

d) The jet velocity in a Pelton turbine is 65 m/s. the peripheral velocity of the runner is 25 m/s. The jet is deflected by 160 degrees by the bucket. Determine the power developed and hydraulic efficiency of the turbine for a flow rate of 0.9 m^3/s. the blade friction coefficient is 0.9. Draw the velocity triangles indicating the values of all velocities on the diagram. **(5 Marks)**

Question (4) (17 Marks)

a) Draw energy conservation diagram for Francis turbine to convert a given hydraulic power into a useful mechanical power. **(3 Marks)**

b) A Francis turbine works under a head of 120 m and is used to be connected to an electric generator. The inner diameter and width are 2 m and 0.16 m. the outer diameter and width are 1.2 m and 0.27 m. the flow velocity at inlet is 8.1 m/s. The whirl velocity at outlet is zero. The outlet blade angle is 16 degrees. Assume the hydraulic efficiency as 90%. Determine, power, speed, specific speed, and blade angle at inlet and guide blade angle. If the discharge is reduced to its half value by varying the guide blades angle under the same head. Find the new power, hydraulic effieiceny, inlet guide blade angle, and outlet water angle to the draft tube. **(8 Marks)**

c) The inlet of a draft tube of a reaction turbine is 2.5 m above the tail race level. The outlet area is 3 times the inlet area. Velocity at inlet is 8 m/s. Kietic head recovery is 80%. Considering atmospheric head as 10 m water column, Determine the pressure at the draft tube inlet. **(6 Marks)**

With My Best Wishes	*Dr. Ahmed Abdo*	*Dr. Mohamed E. Zayed*

The third question (10 marks)

Find the equation of the robot trajectory for the 1 DOF robot arm shown in Figure 3. it is required to move the robot to the new position $(\frac{a_1}{\sqrt{2}}, \frac{a_1}{\sqrt{2}})$ starting from the robot's zero position. The robot takes 2 sec to move to the new position with zero initial and final velocity.

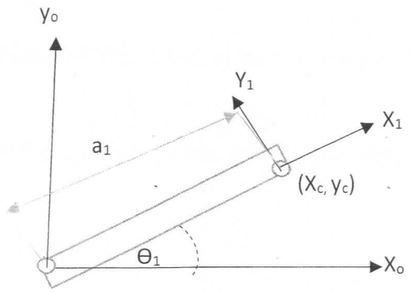


Figure 3

The fourth question (10 marks)

For the following 3-DOF robot shown in Figure 4, find the angular velocity of point C3 with respect to the base frame $x_0y_0z_0$ where l_i and c_i refer to the link length and centre of mass and i=1,2,3.

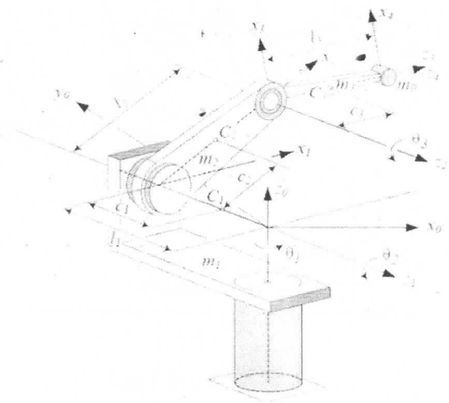


Figure 4

Final EXAM 2022/2023 - Second Term

Course	Robotics (MEP)	Time	3 hour
Mark	85		
Date	8 / 6 /2023	Number of pages	3

The first question (20 marks)

Find the inverse kinematics for the 3 DOF robot arm (RRR) shown in Figure 1 if the end effector has a position (x_c,y_c,z_c). How to solve the problem of singularity for this robot?

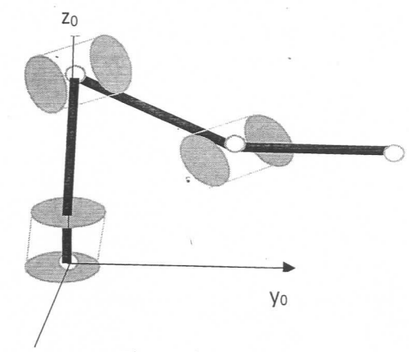


Figure 1

The second question (15 marks)

For the planar polar manipulator shown in Figure 2, find the dynamic equation of motion where it has a massless link and a massive point m.

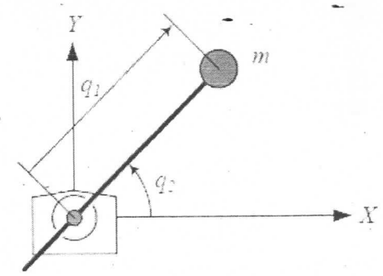


Figure 1

The fourth question (30 marks)

A humanoid robot is shown in Figure 5; the schematic 3-D model of the biped robot and its DOFs is shown in the Figure. Assuming all the joints are revolute and the length of the thigh, shank and between the two hips (HH) are L_{thigh},L_{shank}, and L_{HH} cm, respectively as shown. The weight is concentrated at the motor of each joint, m_{hip}, m_{knee} , m_{ankle} for the hip, knee and ankle, respectively.

(a) Find the transformation matrix between the ankle (x_a $y_a z_a$) with respect to the pelvis ($x_p y_p z_p$).

(b) Find the linear velocity of the ankle with respect to the hip.

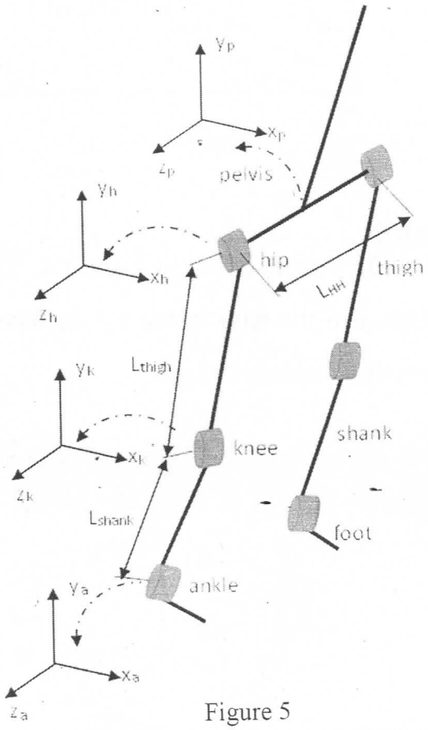


Figure 5

Good Luck
Dr. Ali Mamdouh

Tanta University | **Mechanical Power Engineering Dept.** | **Faculty of Engineering**

Total Marks: 75 marks

Course Title: Elective Course (5)
Gas Turbine Engines
Date: 5th June 2023 (Final Exam)

Course Code: MEP4232
Allowed Time: 3 hrs.
نموذج A

Final Written Exam
No. of Pages: 4 pages

ANSWERS **WITHOUT** ANALYSIS STEPS **WILL NOT BE EVALUATED**

اكتب رقم نموذج ورقة الأسئلة في اول صفحة في كراسة الاجابة

Question No.1: *Identify* ***the choice*** *that best completes the statement or answers the question.*
[15 Marks]

1. Using ____ fuel injectors leads to the first smokeless combustors.

   a. air blast
   b. premix/prevaporizing
   c. vaporizing
   d. pressure atomizing

2. The liner must be designed and built to withstand extended high

   a. vibrations
   b. mechanical cycles
   c. temperature cycles
   d. all the above

3. _____is airflow injected through holes in the liner at the end of the combustion chamber to help cool the air to before it reaches the turbine stages.

   a. Intermediate air
   b. Dilution air
   c. Primary air
   d. Cooling air

4. Using _____fuel injectors leads to incomplete or uneven combustion which has more pollutants and smoke.

   a. premix/prevaporizing
   b. vaporizing
   c. pressure atomizing
   d. air blast

5. In some systems ignition-assist techniques are used. One such method is _____ injection.

   a. fuel
   b. oxygen
   c. air
   d. all the mentioned

6. Typical BWR of gas turbines range from ____

   a. 1 to 2%
   b. 40 to 80%
   c. 10 to 20%
   d. non of the mentioned

7. For Brayton cycle with intercooling between two stages of compressors, the efficiency _____ compared to ideal Brayton cycle.

   a. unpredictable
   b. inceases
   c. decreases
   d. remains constant

8. Bypass ratio in turboprop engine could reach up to _____

   a. 1000
   b. 100
   c. 10
   d. 1

9. For fixed maximum and minimum temperatures, what is the effect of increasing the pressure ratio on the thermal efficiency?

   a. Decreases
   b. unpredictable
   c. Increases
   d. remains constant

10. The BWR of vapor power plants could range from_____

    a. 40 to 80%
    b. non of the mentioned
    c. 1 to 2%
    d. 10 to 20%

11. _____is airflow that is injected through small holes in the liner to generate a layer of cool air to protect the liner from the combustion temperatures.

    a. Intermediate air
    b. Cooling air
    c. Dilution air
    d. Primary air

12. _____ cooling results in a much more even temperature profile of the liner

    a. Air
    b. Primary
    c. Transpiration
    d. Film

13. Thrust in turbofan engine has been increased due to inceasing_____

    a. fuel flow rate
    b. pressure ratio
    c. non of the mentioned
    d. air flow rate

14. Most modern gas turbine engines particularly for aircraft applications do not use_____combustors, as they often weigh more than alternatives.

    a. cannular
    b. can
    c. annular
    d. double annular

15. _____combustor focuses on reducing NOx and CO2 emissions.

    a. double annular
    b. cannular
    c. can
    d. annular

Question No.2: *Identify **one** or **more choices** that best complete the statement or answer the question.*
[15 Marks]

A gas-turbine plant operates on the regenerative Brayton cycle with two stages of compression and two stages of expansion between the pressure limits of 100 and 1500 kPa. The working fluid is air. The air enters the first and the second stages of the compressor at 300 K and 350 K, respectively, and the first and the second stages of the turbine at 1500 K and 1400 K, respectively. Assuming both the compressor and the turbine have an isentropic efficiency of 80 percent and the regenerator has an effectiveness of 75 percent,
Determine
(a) the back work ratio.
(b) the thermal efficiency.
(c)and also draw T-S diagram of the cycle.

* Select the option with closest value to the answer

a. 55%
b. 59%
c. 51%
d. 44%
e. 39%
f. 41%

Question No.3: *Identify **one** or **more choices** that best complete the statement or answer the question.*
[15 Marks]

A turbojet aircraft is flying with a velocity of 350 m/s at an altitude of 9150 m, where the ambient conditions are 32 kPa and 32°C. The pressure ratio across the compressor is 15, and the temperature at the turbine inlet is 1500 K. Air enters the compressor at a rate of 60 kg/s, and the jet fuel has a heating value of 45,000 kJ/kg. Assuming ideal operation for all components and constant specific heats for air at room temperature,
Determine
(a) the velocity of the exhaust gases in m/s,
(b) the propulsive power developed in kW, and
(c) the rate of fuel consumption in kg/s.

* Select the option with closest value to the answer

a. 1.35
b. 1050
c. 1.2
d. 1105
e. 16050
f. 1150
g. 1.05
h. 14050

Question No.4: *Answer the following questions.*
[15 Marks]

A) In an axial flow compressor, air enters at a stagnation temperature of 290K and a stagnation pressure of 1 bar. The axial velocity of air is 180 m/s (constant throughout the stage), the absolute velocity at the inlet is 185 m/s, the work done factor is 0.86, and the degree of reaction is 50%. If the stage efficiency is 0.86, and the rotor speed is 200 m/s. Calculate:
a) The air angles at the rotor inlet and outlet.
b) The static temperature at the inlet of the first stage.
c) Stage pressure ratio.

B) The following design data apply to an axial flow compressor: Overall pressure ratio is 4.5, mass flow is 3.5 kg/s, polytropic efficiency is 0.87, stagnation temperature rise per stage is 22K, absolute velocity approaching the last rotor is 160 m/sec, absolute velocity angle (measured from the axial direction) is 20 °C, work done factor is 0.85, mean diameter at the last stage rotor is 18.5 cm, ambient pressure is 1 bar, and ambient temperature is 290K. Assume equal temperature rise in all stages, and symmetrical velocity diagram. Calculate the following:
a) The number of stages required.
b) Pressure ratio of the first and last stages.
c) Rotational speed.
d) The length of the last stage rotor blade at inlet to the stage.

Question No.5: *Answer the following questions.*
[15 Marks]

A) Explain the working principle of gas turbines. Then Give a general classification of them and illustrate the main differences between axial and radial flow gas turbines.

B) Compare between industrial gas turbine (power station) and aircraft gas turbine engines.

C) Define the following terms of single stage axial flow turbine, (1) degree of reaction and (2) total to static efficiency. Support you answer with the drawing of T-S diagram.

D) In a single-stage axial flow gas turbine, gas enters at stagnation temperature of 1100 K and stagnation pressure of 5 bar. Axial velocity is constant through the stage and equal to 250 m/s. Mean blade speed is 350 m/s. Mass flow rate of gas is 15 kg/s and assume equal inlet and outlet velocities. Nozzle efflux angle is 63°, stage exit swirl angle equal to 9°. Determine the rotor-blade gas angles, degree of reaction, and power out.

Tanta University		Department: Mechanical Power Engineering		Faculty of Engineering
Course Title: Desalination		Course Code: MEP	4rd : years	
Date: 8 6 – 2023	Allowed time: 3 hr Full Marks: (85)		No of Pages: 4	
Name: Prof. Dr. Mohamed Abdelgaied Ahmed			Final Exam	

Answer the following questions: Assume any necessary assumptions.

Question No. 1 **Marks** (30)

a)-For the Brine circulation MSF process prove that:

$$\frac{M_r}{M_d} = \frac{1}{1-(1-y)^n}$$

b)- An MSF-once through process with 24 stages is used to produce 378.8 kg/s of product water. The following specifications are made to obtain the system design parameters and performance characteristics. The specifications include the following:

- Feed seawater temperature, $T_f = 25$ °C.
- Steam temperature, $T_s = 116$ °C.
- Top brine temperature, $T_o = 106$ °C.
- Brine temperature in the last stage, $T_n = 40$ °C.
- Heat capacity of liquid streams, $C_p = 4.18$ kJ/kg°C.
- Salinity of intake seawater, $X_f = 42000$ ppm.
- Salinity of the brine blow-down, $X_b = 70000$ ppm.

Calculate: Feed seawater flow rate, brine flow rate, performance ratio, mass flow rate of heating steam, and heat transfer area.

Question No. 2 (30)

A four effect forward feed MEE-TVC system operates at the following conditions:

- Distillate water productivity = 1 kg/s.
- Seawater temperature $T_{cw} = 25$ °C.
- Feed water temperature leaving the last preheater $t_{f2} = T_1 - 5$ °C.
- Seawater salinity $X_f = 40000$ ppm.
- Salinity of reject brine $X_n = X_b = 70000$ ppm.
- Heating steam temperature $T_s = 60$ °C.
- Pressure of the motive steam $P_m = 250$ kPa.
- Vapor temperature in the last effect $T_n = 40$ °C.
- The thermodynamic losses in each effect, $\Delta T_{loss} = 2$ °C
- The heat capacity of all liquid streams is constant, $C_p = 4.2$ kJ/kg °C.

- The overall heat transfer coefficient in the condenser, $U_c = 1.75$ kJ/s m^2 °C.
- The overall heat transfer coefficient in first effect, $U_1 = 2.4$ kJ/s m^2 °C, this value decreases by 5 % in the each subsequent effect.

Calculate the following:

1) Plant performance ratio.
2) Specific heat transfer area.
3) Specific flow rate of cooling water.

Question No. 3 (25)

a) Discuss with drawing the types of membrane.

b) Design a single stage RO desalination system by calculating the permeate salinity, the brine salinity, the brine flow rate, and the membrane area.

Data

- Water permeability is 2.05 x 10-6 kg /m^2 s kPa.
- Salt permeability is 2.03 x l0-5 kg/m^2 s.
- Feed salinity is 42,000 ppm.
- Feed flow rate: 2.5 kg/s.
- Permeate flow rate: 1 kg/s.
- Feed pressure: 8000 kPa.
- Reject pressure: 7800 kPa.
- Permeate pressure: 101 kPa.

Good luck

$$\lambda_V = 2499.5698 - 2.204864\,T_V - 2.304\text{x}10^{-3}\,T_V^{\,2}$$

Entrained ratio R_a:

$$R_a = \frac{M_m}{M_{ev}} = 0.296\,\frac{(P_s)^{1.19}}{(P_{ev})^{1.04}} \times \left(\frac{P_m}{P_{ev}}\right)^{0.015} \times \left[\frac{PCF}{TCF}\right]$$

Where:

$PCF = [3 \times 10^{-7}(P_m)^2 - 0.0009 \times (P_m) + 1.6101]$ *Take:* P_m *(kPa)*

$TCF = 2 \times 10^{-8}(T_{ev})^2 - 0.0006 \times (T_{ev}) + 1.0047$

Compression ratio: $C_r = \frac{P_s}{P_{ev}}$

Expansion ratio: $E_r = \frac{P_m}{P_{ev}}$

Table Variation in saturation pressure of water vapor (kPa) as a function of temperature (°C)

T (°C)	Calculated Pressure (kPa)	Pressure from Steam Tables (kPa)	Percentage Error
50	12.349	12.35	5.41E-03
55	15.758	15.758	8.65E-04
60	19.940	19.941	2.93E-03
65	25.033	25.03	1.05E-02
70	31.188	31.19	6.73E-03
75	38.577	38.58	7.77E-03
80	47.389	47.39	1.63E-03
85	57.833	57.83	5.57E-03
90	70.138	70.14	3.22E-03
95	84.552	84.55	2.72E-03
100	101.348	101.3	4.72E-02
105	120.817	120.8	1.40E-02
110	143.275	143.3	1.77E-02
115	169.059	169.1	2.45E-02
120	198.529	198.5	1.46E-02
125	232.069	232.1	1.32E-02
130	270.086	270.1	5.30E-03
135	313.007	313	2.39E-03
140	361.287	361.3	3.59E-03
145	415.399	415.4	1.34E-04
150	475.843	475.9	1.21E-02
155	543.137	543.1	6.79E-03
160	617.825	617.8	4.03E-03

Table: Variation in latent heat of water evaporation in (kJ/kg) as a function of temperature (°C)

T (°C)	Calculated Latent Heat (kJ/kg)	Latent Heat from Steam Tables (kJ/kg)	Percentage Error
5	2489.89	2489.56	0.013241
10	2477.93	2477.75	0.007259
15	2466.006	2465.93	0.003078
20	2454.106	2454.12	0.000577
25	2442.218	2442.3	0.003365
30	2430.33	2430.48	0.006175
35	2418.43	2418.62	0.007845
40	2406.507	2406.72	0.008854
45	2394.548	2394.77	0.009271
50	2382.542	2382.75	0.008746
55	2370.476	2370.66	0.007767
60	2358.339	2358.48	0.005984
65	2346.119	2346.21	0.00389
70	2333.804	2333.84	0.001563
75	2321.381	2321.37	0.000489
80	2308.84	2308.78	0.002614
85	2296.169	2296.05	0.005166
90	2283.354	2283.19	0.007192
95	2270.385	2270.19	0.008602
100	2257.25	2257.03	0.009743
105	2243.936	2243.7	0.010528
110	2230.432	2230.2	0.010415
115	2216.726	2216.5	0.010206
120	2202.806	2202.61	0.008904
125	2188.66	2188.5	0.007316
130	2174.276	2174.17	0.004888
135	2159.643	2159.59	0.002441
140	2144.748	2144.76	0.00058
145	2129.579	2129.65	0.00334
150	2114.125	2114.26	0.006395
155	2098.373	2098.57	0.009369
160	2082.313	2082.56	0.01187

The overall heat transfer coefficient

$$U_b = 1.7194 + 3.2063\text{x}10^{-3}\,T_s + 1.5971\text{x}10^{-5}\,(T_s)^2 - 1.9918\text{x}10^{-7}(T_s)^3$$

$$U_c = 1.7194 + 3.2063\text{x}10^{-3}\,T_{v_1} + 1.5971\text{x}10^{-5}\,(T_{v_1})^2 - 1.9918\text{x}10^{-7}(T_{v_1})^3$$

$$U_r = 1.7194 + 3.2063\text{x}10^{-3}\,T_{v_1} + 1.5971\text{x}10^{-5}\,(T_{v_1})^2 - 1.9918\text{x}10^{-7}(T_{v_1})^3$$