POLITEKNIK
Jabatan Pengajian Politeknik

EXAMINATION AND EVALUATION DIVISION
DEPARTMENT OF POLYTECHNIC EDUCATION
(MINISTRY OF HIGHER EDUCATION)

MECHANICAL ENGINEERING DEPARTMENT

FINAL EXAMINATION

DECEMBER 2011 SESSION

JJ207 : THERMODYNAMICS 1

DATE : 25 APRIL 2012 (WEDNESDAY)
DURATION : 2 HOURS (8.30 AM - 10.30 AM)

This paper consists of **SIXTEEN (16)** pages including the front page.
Section A: Objective (25 questions – answer all
Section B: Essay (4 questions – answer 3 questions)

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(CLO stated at the end of each question is referring to the learning outcome of the topic assessed. The CLO stated is only for lectures' references.)

SECTION A

OBJECTIVE (25 marks)

Instructions: This section consists of **TWENTY FIVE (25)** objective questions.

Answer **ALL** questions in the answer booklet.

1. Heat is transferred by THREE (3) methods: [CLO 1]

   i. Conduction
   ii. Reaction
   iii. Convection
   iv. Radiation

   A. i and ii
   B. i, ii and iii
   C. i, iii and iv
   D. All of the above

2. *"When a system undergoes a thermodynamic cycle then the net heat supplied to the system from its surroundings is equal to the net work done by the system on its surroundings."*

   The statement above is about: [CLO 2]

   A. Zeroth Law of Thermodynamics
   B. First Law of Thermodynamics
   C. Second Law of Thermodynamics
   D. Third Law of Thermodynamics

3. All the statements below about Work (*W*) are true **EXCEPT**: [CLO 2]
   A. When work is released from the system, it is denoted as negative.
   B. Work is defined as a product of the force and the distance moved in the direction of the force, W=F x S.
   C. The unit of work is Joule (J) or Nm.
   D. When work is transferred from the surroundings to the system, it is denoted as negative.

4. The following are the units for temperature **EXCEPT**: [CLO 1]
   i. Joule
   ii. Celcius
   iii. Kelvin
   iv. Newton
   A. i and ii
   B. i and iv
   C. i and iii
   D. All of the above

5. What is the function of nozzles and diffusers? [CLO 2]
   A. Nozzles and diffusers increase power in the system.
   B. Nozzles and diffusers are properly shaped ducts which are used to increase or decrease the speed of the fluid flowing through it.
   C. Nozzles and diffusers give a steady flow process
   D. Nozzles and diffusers transfer energy between a closed and open system.

6. *'Liquid is converted to vapours'*. This statement shows the function of a _____ [CLO 1]
   A. compressor
   B. turbine
   C. nozzle
   D. boiler

7. There are two ways energy can be transferred, _____. [CLO 1]
   A. by velocity and condensation
   B. by work and heat
   C. by enthalpy and mass flow
   D. by tube and wire

8. What is a Steady Flow Process? [CLO 2]
   A. A process in which matter and energy flow steadily in and out of an open system.
   B. A process that causes a pressure drop in a flowing fluid.
   C. A process that causes an increase in the pressure of a gas.
   D. A process where two or more fluid streams are mixed.

9. *'If system A and system B are in thermal equilibrium with system C, then system A is in thermal equilibrium with system B.....'*. This statement is taken from the_____. [CLO 1]
   A. Zeroth Law of Thermodynamics
   B. First Law of Thermodynamics
   C. Second Law of Thermodynamics
   D. Third Law of Thermodynamics

10. Which of the following is the **CORRECT** assumption for the boiler system? [CLO 2]
    A. There is no heat and work transferred.
    B. There is no change an internal energy and enthalpy.
    C. There is no work done on the boiler while kinetic energy and potential energy are neglected.
    D. There is no mass flow rate

11. An automobile tyre with a volume of 0.6 m^3 is inflated to a gauge pressure of 200 kPa. Calculate the mass of air in the tyre if the temperature is 20°C. Given P_{atm} = 100 kPa [CLO 1]

    A. 2.14 kg
    B. 2.24 kg
    C. 1.43 kg
    D. 2.43 kg

12. The phase change from liquid to vapour is referred to as _____ [CLO 1]
    A. Vaporization
    B. Condensation
    C. Sublimation
    D. Melting

13. The point that connects the saturated liquid line to the saturated vapour line is called the : [CLO 1]
    A. Triple point
    B. Critical point
    C. Superheated point
    D. Compressed liquid point

14. Find the enthalpy of dry saturated vapour at 103 bar. [CLO 1]
    A. 2719 kJ/kg
    B. 2722 kJ/kg
    C. 2725 kJ/kg
    D. 2715 kJ/kg

15. Find the saturated temperature at 20 bar. [CLO 1]
    A. 490.2 °K
    B. 487.8 °K
    C. 485.4 °K
    D. 491.3 °K

16. In a compression stroke for gas engine, work done by the piston on the gas is 70 kJ/kg. The amount of heat transferred out is 42 kJ/kg. Calculate the difference of internal energy. [CLO 1]
    A. 28 kJ/kg
    B. -28 kJ/kg
    C. 112 kJ/kg
    D. -112 kJ/kg

17. Which of the following statements are **TRUE** about heat engines? [CLO 2]
    i. They receive heat from a high-temperature source (solar energy, oil furnace, etc.).
    ii. They convert part of heat to work.
    iii. They reject the remaining waste heat to a low-temperature sink (the atmosphere, rivers, etc.).
    iv. They operate on a cycle.

    A. i and ii
    B. ii and iii
    C. i, ii and iv
    D. i, ii, iii and iv

18. An ideal gas at 170 kN/m^2 and 320 °C operates at constant volume until its temperature reaches 5000 °C and volume of 0.025 m^3. It is then operated at constant pressure to 0.037 m^3. Finally it is compressed adiabatically back to the original state. Determine the volume after the adiabatic process. [CLO 1]

A. 0.012 m^3

B. 0.025 m^3

C. 0.055 m^3

D. 0.063 m^3

19. Heat is transferred to a heat engine from a furnace at a rate of 80 MW. If the rate of heat rejection to a nearby river is 50 MW, what is the thermal efficiency for this heat engine? [CLO 2]

A. 6%

B. 60%

C. 3.75%

D. 37.5%

20. The formulas given below are used in calculating properties of a wet steam, **EXCEPT** : [CLO 1]

A. $v = xv_g$

B. $h = h_f + xh_{fg}$

C. $u = u_f + x(u_g - u_f)$

D. $s = s_f + x(s_f - s_g)$

21. Choose the **CORRECT** examples of heat engines. [CLO 2]

A. Gas turbine engines and steam power cycle.

B. Gas turbine engines and refrigerators.

C. Gas turbine engines and air conditioning.

D. Refrigerators and air conditioning.

22. Which statement is **FALSE** about the Second Law of Thermodynamics? [CLO 2]

A. Gross heating value must be greater than the net work.

B. Net heat supplied in a cycle is equal to the net work done, where some heat was rejected from the system.

C. All processes in the cycle are reversible.

D. The heat supplied is equal to heat released.

23. What kind of process is shown in the T-s diagram (Figure 23) below? [CLO 1]

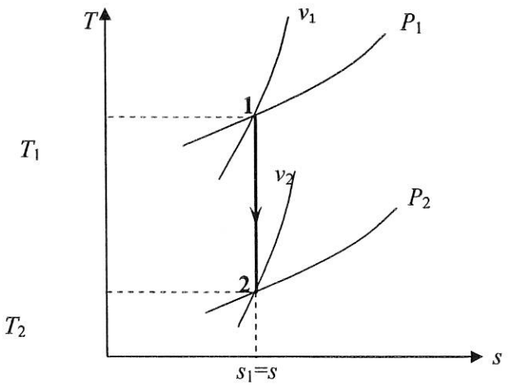

Figure 23 : T-s diagram

A. Polytrophic process

B. Isentropic process

C. Constant volume process

D. Constant pressure process

24. Which of the following are examples for a heat pump? [CLO 2]

i. Refrigerator

ii. Air-conditioner

iii. Heat engine

iv. Diesel engine

A. i and ii

B. ii and iii

C. iii and iv

D. i, ii and iii

25. Heat is transferred to a heat engine from a furnace at a rate of 98 MW. If the rate of waste heat rejection to a nearby river is 50 MW, determine the thermal efficiency for this heat engine. [CLO 2]

A. 57 %

B. 49 %

C. 23 %

D. 60 %

SECTION B

ESSAY (75 marks)

INSTRUCTION:

This section consists of **FOUR (4)** questions. Answer **THREE (3)** questions only.

QUESTION 1

(a) List **SIX (6)** SI (International System) units and their symbols. [CLO 1]

(6 marks)

(b) Convert the units below: [CLO 1]

i) 7 km/h to m/s.

ii) 35 g/mm^3 to kg/m^3.

iii) 18 milligram per litre to kg/m^3.

(9 marks)

(c) Based on the Fundamental concepts and with the aid of a sketch, explain: [CLO 1]

i) system

ii) boundary

iii) surroundings

(6 marks)

(d) Explain briefly, what is a closed system. [CLO 1]

(4 marks)

QUESTION 2

(a) With a p-v diagram, label all the properties/phases below. [CLO1]

(i) Compress liquid region
(ii) Saturated liquid line
(iii) Wet steam region
(iv) Dry saturated steam line
(v) Superheated steam region
(vi) Critical point

(4 marks)

(b) Find the dryness fraction, specific enthalpy and specific internal energy of steam at 175 bar and specific entropy of 4.832 kJ/kgK [CLO1]

(9 marks)

(c) A compressor containing 0.12 kg of air has a pressure of 2.2 bar, a volume of 0.08 m3. After polytrophic (PV1.3= C) process, the pressure of the air is 12 bar. Determine :- [CLO1]

(i) Final volume
(ii) The amount and direction of work energy for the compression
(iii) The quantity and direction of heat energy during the process

Assume R= 0.287kJ/kgK and C_v = 0.72 kJ/kgK (12 marks)

QUESTION 3

(a) Determine: [CLO 1]

i. The quality of steam at a pressure of 140 bar if the specific enthalpy is 2034 kJ/kg.

(3 marks)

ii. The pressure of steam at 150°C with an entropy of 7.38 kJ/kg K.

(4 marks)

(b) An insulated cylinder initially has 130 kPa at 304 K and the gas has been expanded to 615 K. The work of 97.43 kJ was done on the system during the expansion process. If the gas has a mass of 0.7 kg, determine the final

pressure (unit: bar) and final volume of the gas. Given C_p = 865 J/kgK and C_v = 0.445 kJ/kgK. [CLO 1]

(14 marks)

(c) A reversible heat engine is used to maintain a house at 19°C during summer. The outdoor temperature is 45°C and the heat loss is estimated to be 30 kW. If the required Coefficient of Performance is 2.7, determine the heat absorbed and the power consumed. [CLO 2]

(4 marks)

QUESTION 4

(a) Based on steady flow energy equation, explain [CLO2]

i. Potential energy

ii. Kinetic energy

iii. Internal energy

(6 marks)

(b) The steady flow energy equation may be applied to any apparatus. With a sketch, explain the application of the steady flow energy in [CLO2]

i. The boiler

ii. The condenser

(10 marks)

(c) In a steady flow system, a substance flows at the rate of 4 kg/s. It enters the system at a pressure of 620 kN/m^2, a velocity of 300 m/s, internal energy 2100 kJ/kg and specific volume of 0.37 m^3/kg. It leaves the system at a pressure of 130 kN/m^2, a velocity of 150 m/s, internal energy 1500 kJ/kg and specific volume of 1.2 m^3/kg. During its passage through the system, the substance has lost energy by heat transfer of 30 kJ/kg to the surroundings. Determine the power of the system in kilowatts and state whether it is from or to the system. Ignore any changes in potential energy. [CLO2]

(9 marks)

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1. FIRST LAW OF THERMODYNAMICS

$\Sigma Q = \Sigma W$ $\quad Q - W = U_2 - U_1$

2. FLOW PROCESS

$\dot{m} = \rho VA = \rho \dot{V}$ (kg/s) $= \dot{m} = \dfrac{CA}{V}$

$$Q - W = \dot{m}\left[(h_2 - h_1) + \left(\frac{C_2^{\,2} - C_1^{\,2}}{2}\right) + (Z_2 - Z_1)g\right]$$

$$Q_T - W_T = \left[(h_2 - h_1) + \left(\frac{C_2^{\,2} - C_1^{\,2}}{2}\right) + (Z_2 - Z_1)g\right] \qquad h = u + pv$$

3. PROPERTIES OF PURE SUBSTANCE

Steam

$v = xv_g$ $\quad h = h_f + xh_{fg}$ $\quad u = u_f + x(u_g - u_f)$ $\quad s = s_f + xs_{fg}$

Ideal Gas

$PV = mRT$ $\quad R = \dfrac{R_o}{M}$ $\quad R = C_p - C_v$ $\quad \gamma = \dfrac{C_p}{C_v}$

Non-Flow Process

1. **Isothermal Process** ($PV = C$)

$U_2 - U_1 = 0$ $\quad Q = W$

$$W = P_1V_1 \ln\left(\frac{V_2}{V_1}\right) \quad @ \quad W = P_1V_1 \ln\left(\frac{P_1}{P_2}\right)$$

$$Q = P_1V_1 \ln\left(\frac{V_2}{V_1}\right) \quad @ \quad Q = P_1V_1 \ln\left(\frac{P_1}{P_2}\right)$$

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2. Adiabatic Process *($PV^{\gamma} = C$)*

$U_2 - U_1 = mC_v(T_2 - T_1)$ $\quad W = \frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{mR(T_1 - T_2)}{\gamma - 1}$

$Q = 0$ $\quad \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

3. Politropic Process ***($PV^n = C$)***

$U_2 - U_1 = mC_v(T_2 - T_1)$ $\quad W = \frac{P_1V_1 - P_2V_2}{n - 1} = \frac{mR(T_1 - T_2)}{n - 1}$

$Q = \frac{\gamma - n}{\gamma - 1} \times W$ $\quad \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}$

4. Isobaric Process

$U_2 - U_1 = mC_v(T_2 - T_1)$

$W = P(V_2 - V_1) = mR(T_2 - T_1)$

$Q = mC_p(T_2 - T_1)$

5. Isometric Process

$U_2 - U_1 = mC_v(T_2 - T_1)$

$W = 0$

$Q = U_2 - U_1 = mC_v(T_2 - T_1)$

4. <u>SECOND LAW OF THERMODYNAMICS</u>

Heat Engine

$$\eta_{th} = \frac{W_{net,out}}{Q_H} = 1 - \frac{Q_L}{Q_H}$$

Refrigerator

$$COP_{R,rev} = \frac{T_L}{T_H - T_L} = \frac{1}{T_H / T_L - 1}$$

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Heat Pump

$$COP_{HP,rev} = \frac{T_H}{T_H - T_L} = \frac{1}{1 - T_L / T_H}$$

Entropy

$$S_{gen} = \Delta S_{total} = \Delta S_{system} + \Delta S_{surrounding} = 0$$

$$\left(\frac{P_2}{P_1}\right)_{isentropic} = \left(\frac{P_{r2}}{P_{r1}}\right)$$

$$\left(\frac{v_2}{v_1}\right)_{isentropic} = \left(\frac{v_{r2}}{v_{r1}}\right)$$

STEAM

a) Isobaric process
$W = P(V_2 - V_1)$ *atau* $W = Q - (u_2 - u_1)$

$Q = h_2 - h_1$

b) Isometric Process
$W = 0$

$Q = u_2 - u_1$

c) Isothermal Process
$Q = T(s_2 - s_1)$

$W = Q - (u_2 - u_1)$

d) Adiabatic/Isentropic Process
$s_1 = s_2$

$Q = 0$

$W = u_1 - u_2$

e) Politropic Process

$$W = \frac{P_1V_1 - P_2V_2}{n - 1}$$

$$Q = (u_2 - u_1) + W$$

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PERFECT GAS

a) *Isobaric process*

$$s_2 - s_1 = mC_p \ln\left(\frac{T_2}{T_1}\right)$$

b) *Isometric Process*

$$s_2 - s_1 = mC_v \ln\left(\frac{T_2}{T_1}\right)$$

c) *Isothermal Process*

$$s_2 - s_1 = mR \ln\left(\frac{v_2}{v_1}\right) = mR \ln\left(\frac{p_1}{p_2}\right)$$

d) *Politropic Process*

$$s_2 - s_1 = mR \ln\left(\frac{v_2}{v_1}\right) - mC_v \ln\left(\frac{T_1}{T_2}\right) \quad \text{atau} \quad s_2 - s_1 = mR \ln\left(\frac{p_1}{p_2}\right) - mC_p \ln\left(\frac{T_1}{T_2}\right)$$