UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2016/2017

COURSE NAME	:	CHEMICAL ENGINEERING THERMODYNAMICS
COURSE CODE	:	BNQ 20104
PROGRAMME CODE	:	BNN
EXAMINATION DATE	:	DECEMBER 2016 / JANUARY 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

Q1 (a) (i) List **FOUR (4)** processes that make up the simple ideal Rankine cycle.
(4 marks)

(ii) Excessive moisture in steam is undesirable in steam turbines. Explain the level of the highest moisture content allowed with definite reason.
(1 mark)

(b) A steam power plant operates on the cycle shown in **Figure Q1(b)**. If the isentropic efficiency of the turbine is 87% and the isentropic efficiency of the pump is 85%, determine:

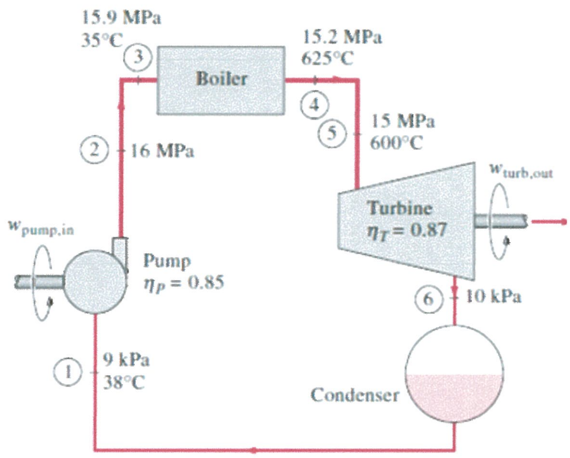

Figure Q1(b)

(i) The thermal efficiency of the cycle.
(5 marks)

(ii) The net power output of the plant for a mass flow rate of 15 kg/s.
(2 marks)

(c) Consider a steam power plant that operates on a simple ideal Rankine cycle and has a net power output of 45 MW. Steam enters the turbine at 7 MPa and 500°C and is cooled in the condenser at a pressure of 10 kPa by running cooling water from a lake through the tubes of the condenser at a rate of 2000 kg/s.

(i) Show the cycle on a *T-s* diagram with respect to saturation lines.
(2 marks)

(ii) Determine the thermal efficiency of the cycle.
(3 marks)

(iii) Determine the mass flow rate of the steam.
(1 mark)

(iv) Determine the temperature rise of the cooling water.
(2 marks)

(d) During a regeneration process, some steam is extracted from the turbine and is used to heat the liquid water leaving the pump. This does not seem like a smart thing to do since the extracted steam could produce some more work in the turbine. Justify this action.

(3 marks)

(e) Consider a simple Rankine cycle and an ideal Rankine cycle with three reheat stages. Both cycles operate between the same pressure limits. The maximum temperature is 700°C in the simple cycle and 450°C in the reheat cycle. Evaluate cycle with high higher thermal efficiency complete with a reason.

(2 marks)

Q2 (a) Using the Maxwell relations,

(i) Determine a relation for $(\partial s/\partial P)_T$ for a gas whose equation of state is $P(v-b)=RT$.

(2 marks)

(ii) Verify the validity of the last Maxwell relation for refrigerant-134a at 80°C and 1.2 MPa.

(3 marks)

(b) Describe how vapour pressure of the ambient air is determined when the temperature, total pressure, and the relative humidity of air are given.

(4 marks)

(c) Show that the enthalpy of an ideal gas is a function of temperature only and that for an incompressible substance it also depends on pressure.

(5 marks)

(d) **Figure Q2(d)** shows an adiabatic 0.2 m^3 storage tank that is initially evacuated is connected to a supply line that carries nitrogen at 225 K and 10 MPa. A valve is opened, and nitrogen flows into the tank from the supply line. The valve is closed when the pressure in the tank reaches 10 MPa. Determine the final temperature in the tank;

(i) Treating nitrogen as an ideal gas.

(2 marks)

(ii) Using generalized charts, compare your results to the actual value of 293 K.

(5 marks)

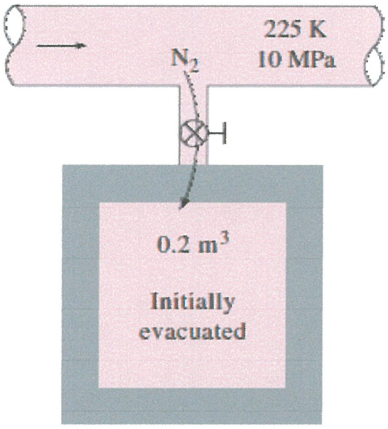

Figure Q2(d)

(e) Derive a relation for the volume expansivity and the isothermal compressibility;

(i) For an ideal gas.

(2 marks)

(ii) For a gas whose equation of state is $P(v - a) = RT$.

(2 marks)

Q3 (a) Identify the difference between the specific humidity and the relative humidity

(2 marks)

(b) Consider a tank that contains moist air at 3 atm and whose walls are permeable to water vapor. The surrounding air at 1 atm pressure also contains some moisture. Is it possible for the water vapor to flow into the tank from surroundings? Explain your answer.

(3 marks)

(c) A 8 m^3 tank contains saturated air at 30 °C, 105 kPa. Calculate;

(i) The mass of dry air.

(2 marks)

(ii) The specific humidity.

(2 marks)

(iii) The enthalpy of the air per unit mass of the dry air.

(2 marks)

(d) **Figure Q3(d)** shows air enters a 30 cm diameter cooling section at 1 atm, 35 °C, and 60% relative humidity at 120 m/min. The air is cooled by passing it over a cooling coil through which cold water flows. The water experiences a temperature rise of 8°C. The air leaves the cooling section saturated at 20°C. Assume this is a steady-flow process and dry air and water vapour are ideal gases. The kinetic and potential energy changes are negligible.

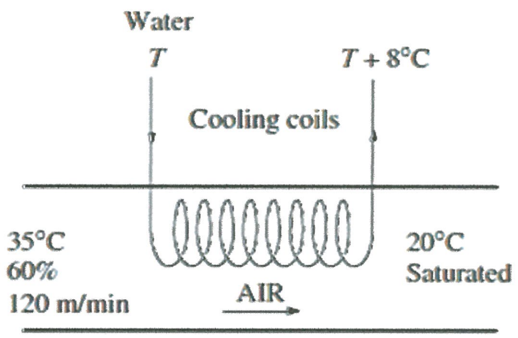

Figure Q3(d)

Determine;

(i) The rate of heat transfer.

(2 marks)

(ii) The mass flow rate of the water.

(2 marks)

(iii) The exit velocity of the airstream.

(4 marks)

(e) In a movie theater during monsoon season, 500 people, each generating sensible heat at a rate of 70 W, are watching a movie. The heat losses through the walls, windows, and the roof are estimated to be 130,000 Btu/h. Determine if the theater needs to be heated or cooled.

(4 marks)

(f) Consider a tennis match in cold weather where both players and spectators wear the same clothes. State the group of people will feel colder and justify.

(2 marks)

Q4 (a) Consider supersonic airflow approaching the nose of a two-dimensional wedge and experiencing an oblique shock. State conditions does an oblique shock detach from the nose of the wedge and form a bow wave. Define the numerical value of the shock angle of the detached shock at the nose.

(2 marks)

(b) Determine the stagnation temperature and stagnation pressure of air that is flowing at 44 kPa, 245.9 K, and 470 m/s.

(4 marks)

(c) Air enters a converging–diverging nozzle of a supersonic wind tunnel at 1.5 MPa and 350 K with a low velocity. If a normal shock wave occurs at the exit plane of the nozzle at Ma = 2.

Determine the pressure, temperature, Mach number, velocity, and stagnation pressure after the shock wave.

(6 marks)

(d) (i) Air enters a converging–diverging nozzle with low velocity at 2.0 MPa and 100°C. If the exit area of the nozzle is 3.5 times the throat area. Determine the back pressure required to produce a normal shock at the exit plane of the nozzle.

(7 marks)

(ii) Based on **Q4 d(i)**, it is a need for the back pressure for a normal shock to occur at a location where the cross-sectional area is twice the throat area. Explain this statement.

(4 marks)

(e) In air-conditioning applications, the temperature of air is measured by inserting a probe into the flow stream. Thus, the probe actually measures the stagnation temperature. Determine if any significant error occurs.

(2 marks)

- END OF QUESTIONS -