## NATI ONAL UNI VERSI TY OF SCI ENCE AND TECHNOLOGY

FACULTY OF I NDUSTRI AL TECHNOLOGY
DEPARTMENT OF I NDUSTRI AL \& MANUFACTURI NG ENGI NEERI NG

## Bachelor of Engineering Honours Degree I ndustrial \& Manufacturing Engineering

INTRODUCTION TO THERMAL SYSTEMS - TIE 3108
$1^{\text {st }}$ SEMESTER EXAMI NATI ONS APRIL 2009

## Instructions to Candidates

## Time Allowed 3 hours

Answer any FIVE questions

## Question 1

a) A boiler generates 5000 kg of steam $/ \mathrm{h}$ at $1.8 \mathrm{MN} / \mathrm{m}^{2}$. The steam temperature is $325^{\circ} \mathrm{C}$ and the feed water temperature is $49.4^{\circ} \mathrm{C}$. The efficiency of the boiler plant is $80 \%$ when using oil of calorific value $45500 \mathrm{~kJ} / \mathrm{kg}$. The steam generated is supplied to a turbine which develops 500 Kw and exhausts at $0.18 \mathrm{MN} / \mathrm{m}^{2}$, the dryness fraction of the steam being 0.98 . Estimate the amount of oil used/h and the fraction of the enthalpy drop through the turbine through the turbine, which is converted into useful work.
b) What are the maintenance problems associated with boilers?

## Question 2

a) A two stage, single acting, reciprocating compressor takes air at the rate of $0.2 \mathrm{~m}^{3} / \mathrm{s}$. Intake pressure and temperature are $0.1 \mathrm{MN} / \mathrm{m}^{2}$ and $16^{0} \mathrm{C}$ respectively. The air is compressed to a final pressure of $0.7 \mathrm{MN} / \mathrm{m}^{2}$. The immediate pressure is ideal and intercooling is perfect. The compression index is 1.25 and the compressor runs at $10 \mathrm{rev} / \mathrm{s}$.

Neglecting clearance, determine:
i. The immediate pressure
ii. The total volume of each cylinder
iii. The cycle power
b) Identify the maintenance problems associated with compressors.

## Question 3

a) Identify and explain the principles of operation of any three types of recuperator
b) A surface condenser operating at a pressure of $24 \mathrm{KN} / \mathrm{m}^{2}$ condenses 1.8 tonne of steam of 0.98 and is condensed, but not undercooled. Cooling water enters the condenser at a temperature of $21^{\circ} \mathrm{C}$ and leaves at $57^{\circ} \mathrm{C}$. Determine the flow rate of the cooling water.

## Question 4

Exhaust gases flowing through a tubular heat exchanger at the rate of $0.3 \mathrm{~kg} / \mathrm{s}$ are cooled from 400 to $120^{\circ} \mathrm{C}$ by water initially at $10^{\circ} \mathrm{C}$. If the specific heat capacities of exhaust gases and water are 1.13 and $4.19 \mathrm{~kJ} / \mathrm{kgK}$ respectively and the overall heat transfer coefficient from gas to water is $140 \mathrm{~W} / \mathrm{m}^{2} \mathrm{~K}$. Calculate the surface area required when the cooling water flows at $0.4 \mathrm{~kg} / \mathrm{s}$ for
i) parallel flow and
ii) counter flow

## Question 5

With the aid of sketches explain the principles of operation of the following plants
i) Cooling tower
ii) Cross flow recuperator
iii) Regenerative heat exchanger

## Question 6

A small size cooling tower is designed to cool 5.5litres of water per second the inlet temperature of which is $44^{\circ} \mathrm{C}$. The motor driven fan induces $9 \mathrm{~m}^{3} / \mathrm{s}$ of air through the tower and the power absorbed is 4.75 Kw . The air entering the tower is at $18^{\circ} \mathrm{C}$ and has a relative humidity of $60 \%$. The air leaving the tower can be assumed to be saturated and its temperature is $26^{\circ} \mathrm{C}$. Assuming that the pressure inside the tower is constant at 1.013bar and makeup water is made outside the tower calculate;
a) The flow rate of make up water required
b) The final temperature of the water leaving the tower.

Take Pg at $18^{\circ} \mathrm{C}=0.02063$ bar

## Question 7

The pressure in the evaporator of an ammonia refrigerator is 1.902 bar and the pressure in the condenser is 12.37 bar . What is the ideal coefficient of performance for machine working between the corresponding saturation temperatures and what is the ideal refrigerating effect per kg of refrigerant and the C.O.P for the practical cycle working between the same pressures, when
(a) dry saturated vapor is delivered to the condenser after isentropic compression and there is no under cooling of the condensed liquid
(b) dry saturated vapor is delivered to the compressor where it is compressed isentropically and there is no under cooling of the condensed liquid.

## Question 8

A steam turbine plant operates on the rankine cycle. Steam is delivered from the boiler to the turbine at a pressure of $3.5 \mathrm{MN} / \mathrm{m}^{2}$ and with a temperature of $350^{\circ} \mathrm{C}$. Steam from the turbine exhausts into the condenser at a pressure of $10 \mathrm{KN} / \mathrm{m}^{2 .}$ Condensate from the condenser is returned to the boiler by means of feed pump. neglecting losses, determine,
a) The energy supplied in the boiler $/ \mathrm{kg}$ of the steam generated.
b) Dryness fraction of steam entering the condenser
c) The Rankine efficiency

## End of Exam

