**UNIVERSITY OF MALTA**
**FACULTY OF ENGINEERING**
**B.ENG.(HONS.) IN MECHANICAL ENGINEERING**
**YEAR III – SEMESTER I**
**JANUARY/FEBRUARY 2013 SESSION OF EXAMINATIONS**

**MEC 2307 – Thermodynamics II** **19th January, 2013**

**13:00 – 16:00 hours**

*This paper contains* **SIX** *questions. You are to attempt* **FIVE**.

*Stationery:* Use of calculators is allowed
Steam Tables

1. Gases expand in a propulsion nozzle from 3.5 bar and 425 $^oC$ down to a back pressure of 0.97 bar, at the rate of 18 kg/s. Calculate the required throat and exit areas of the nozzle assuming negligible inlet velocity and isentropic flow.

   For the gases take $\gamma$ = 1.333 and $c_p$= 1.11kJ/kgK.

   If a coefficient of discharge of 0.99 and a nozzle efficiency of 0.94 are considered, what would be the throat and exit areas?

   ***(20 marks)***

2. The ultimate analysis (by mass) of a sample of petrol was : C 83%; H 14%; $O_2$ 3%. If the dry products had 1 % CO, calculate:
   (a) the stoichiometric A/F ratio
   (b) actual AFR
   (c) the analysis of dry products for the rich operation
   (d) the volume ratio of $H_20$ in the exhaust and the temperature to which the gas must be cooled before condensation of the $H_2O$ vapour begins, if the pressure in the exhaust pipe is 1.013bar.

   ***(20 marks)***

3. In a diesel cycle, air at 1bar and 15$^o$C is compressed isentropically. Heat is then added at constant pressure to 1200$^o$C. The compressed air is expanded isentropically to its initial volume and finally cooled at constant volume to its initial temperature. The compression ratio is 16. Sketch the *pv* diagram for this cycle. Find the work output per kg of air, the heat engine efficiency and the mean effective pressure.

   ***(20 marks)***

4. (a) Show that for a reciprocating air compressor

$$W_i = \frac{n}{n-1}\dot{m}RT_1\left\{\left(\frac{p_2}{p_1}\right)^{(n-1)/n} - 1\right\}$$

***(8 marks)***

(b) A single-stage, double acting air compressor is required to deliver 14 $m^3$ of air per minute measured at the inlet conditions of 1.013 bar and 15°C.
The delivery pressure is 7 bar and the speed 300 rev/min. Take the clearance volume as 5% of the swept volume with a compression and re-expansion index of $n = 1.3$ . Sketch the *pv* diagram. Calculate the swept volume of the cylinder, the delivery temperature, and the indicated power.

***(12 marks)***

5. (a) Show that the efficiency for a Joule Cycle, (ideal GT cycle) with a constant $c_p$ and $\gamma$ throughout the cycle, is given by:

$$\eta = 1 - \frac{1}{r_p^{(\gamma-1)/\gamma}}$$

Where $r_p$ is the pressure ratio, and mass flow is constant throughout cycle, *i.e.* neglect mass of fuel flow.

***(10 marks)***

(b) A GT Cycle works with a pressure ratio of 12. The minimum and maximum temperatures in the cycle are 30°C and 1000°C. The compressor isentropic efficiency is 80% while the turbine isentropic efficiency is 90%. For the compression of air $\gamma$=1.4 and $c_p$= 1.005 kJ/kgK while for the combustion and expansion processes $\gamma$=1.3 and $c_p$= 1.15 kJ/kgK. Calculate

(i) the heat input
(ii) the heat rejection
(iii) the work ratio
(iv) the overall efficiency

***(10 marks)***

6. (a) A vapour compression refrigerator using R12 works between temperature limits of -5°C and 40°C. The refrigerant enters the compressor dry saturated and is at 9.607 bar downstream of the compressor. Calculate the refrigeration effect and coefficient of performance if the refrigerant is sub-cooled to 20°C before entering the throttling valve. If a cooling effect of 3 kW is required, what is the amount of heat rejected from the condenser.

***(10 marks)***

(b) In a regenerative steam cycle employing one open feed heater the steam is supplied to the turbine at 42 bar and 500 °C and is exhausted to the condenser at 0.035 bar. The bleed steam for feed heating is taken at a pressure of 4 bar. Sketch the *Ts* diagram. Assuming ideal processes and neglecting feed pump work, calculate:

(i) the fraction of the boiler steam bled for feed heating

(ii) the power output of the plant per unit mass flow rate of boiler steam

(iii) the cycle efficiency

***(10 marks)***

**Additional information**

$$\frac{T_1}{T_2} = \left(\frac{v_2}{v_1}\right)^{n-1} \quad \text{and} \quad \frac{T_1}{T_2} = \left(\frac{p_1}{p_2}\right)^{(n-1)/n}$$

$$W = \frac{(p_2 v_2 - p_1 v_1)}{n-1} = \frac{R(T_2 - T_1)}{n-1}$$

where $W$ is specific work, $p$ is pressure and $v$ specific volume, n is the polytropic index, $R$ is the specific gas constant and $T$ is the temperature. Subscripts 1 and 2 refer to the states.

$$s_2 - s_1 = c_p \ln\left[\frac{T_2}{T_1}\right] + R \ln\left[\frac{p_1}{p_2}\right]$$

$$\frac{p_c}{p_1} = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}}$$

Where $p_c$ is the critical pressure for a nozzle, $p_1$ is the upstream pressure, and $\gamma$ is the ratio of specific heats i.e. $c_p / c_v$

$$C_c = \sqrt{\gamma R T_c}$$

$$\textit{Nozzle Efficiency} = \frac{C_2^2 - C_1^2}{C_{2s}^2 - C_1^2}$$

$$\textit{Velocity Coefficient} = \frac{C_2}{C_{2s}}$$