UNIVERSITY OF MALTA
FACULTY OF ENGINEERING
B.ENG. (HONS.) COURSE
MECHANICAL ENGINEERING STREAM
YEAR IV – SEMESTER I
JANUARY/FEBRUARY 2014 SESSION OF EXAMINATIONS

MEC4011 – Power Plants **29th January, 2014**

0915 - 1215 hours

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

Stationery: **Use of calculators is allowed**
Steam Tables
Sheets of Useful Equations

1. (a) Draw the velocity diagram for a simple impulse turbine and show that for symmetrical blade with no friction.

$$optimal\left(\frac{C_b}{C_{ai}}\right) = \frac{\cos\alpha_i}{2} \text{ and } \eta_{d\max} = \cos^2\alpha_i$$

(7 marks)

(b) The velocity of steam at inlet to a simple impulse turbine is 1000 m/s, and the nozzle angle is 20^o. The blade speed is 400 m/s and the blades are symmetrical. Determine the blade angles if the steam is to enter the blades without shock. If the friction effects on the blade are negligible, calculate the tangential force on the blades and the diagram power for a mass flow of 0.75 kg/s. What are the axial thrust and the diagram efficiency?

If the relative velocity at exit is reduced by friction to 80% of that at the inlet, what is then the diagram power and the axial thrust? Calculate also the diagram efficiency in this case.

(13 marks)

2. The first stage of a turbine is a two-row velocity compounded wheel. Steam at 40 bar and 400^{o}C is expanded in the nozzle to 15 bar, and the velocity at discharge of the nozzle is 700m/s. The inlet velocity to the stage is negligible. The relevant exit angles are: nozzle 18^{o}; first row blades 21^{o}; fixed blades 26.5^{o}; second row blades 35^{o}. Take the blade velocity coefficient for all blades as 0.9. The mean diameter of the blading is 750mm and the turbine shaft speed is 3000rev/min.

Draw the velocity diagram for this wheel and calculate:

(a) the diagram efficiency
(b) the stage efficiency

(20 marks)

3. (a) Sketch the *pv* diagrams for a naturally aspirated and supercharged diesel engines. Comment of the differences you expect between them.

(4 marks)

(b) A six-cylinder, four stroke CI engine of 75 mm bore and 100 mm stroke has a brake power output of 110 kW at 3750 rev/min. The volumetric efficiency at this operating condition referred to ambient conditions of 1.013 bar and 20^{o}C is 80%.

The engine is now fitted with a mechanically driven supercharger which has an isentropic efficiency of 0.7 and a pressure ratio of 1.6. The supercharged version has a volumetric efficiency of 100% referred to the supercharger delivery pressure and temperature. If it is assumed that the indicated power developed per unit mass flow rated of induced air is the same for normal aspiration and supercharging, calculate the net increase in brake power to be expected from the supercharged engine. Take the mechanical efficiency of the engine as 80% in both cases and the mechanical efficiency of the drive from engine to supercharger as 95%.

(16 marks)

4. (a) What is the Wiebe function used for and what is its approximate shape?

$$X_b = \frac{m_b}{m} = 1 - \exp\left[-\alpha\left(\frac{\theta - \theta_{ign}}{\Delta\,\theta_c}\right)^{\beta+1}\right]$$

(4 marks)

(b) A four-cylinder four-stroke SI racing engine of capacity 2.495 litres has a bore of 94mm and a compression ratio of 12/1. When tested against a dynamometer with a torque arm of 0.461m, a maximum load of 622 N was obtained at 5000 rev/min, and at the peak speed of 6750 rev/min the load was 547 N. The minimum fuel consumption was 17.2 ml/s at a speed of 5000 rev/min, the specific gravity of the fuel being 0.735, and $Q_{net,v}$ = 44200 kJ/kg. Calculate the maximum bmep, the maximum brake power, the minimum specific fuel consumption, and the maximum brake thermal efficiency at maximum torque, and compare this latter answer with the air standard efficiency.

(16 marks)

5. (a) Draw a simple diagram of a surface condenser with separate condensate outlet and screened air outlet. Why is a condenser important in a steam cycle rather than exhaust to atmospheric pressure?

(4 marks)

(b) The condenser of a steam turbine receives 100,000 kg/h of dry saturated steam at a temperature of 37.7^{o}C. The condenser has separate air and condensate outlets and a portion of the cooling surface is screened from the incoming steam and the air passes over these screened tubes to the air extraction and becomes cooled below the condensate temperature. At the condensate outlet the temperature is 36.2^{o}C and at the air extraction the temperature is 29^{o}C. If 25 kg/hr of air is known to be mixed with the steam, calculate

(i) The volume flow rate of air plus vapour required to be pumped out of the condenser.
(ii) How much vapour is lost with the air extraction.
(iii) What is the mass of steam condensed in the air cooler.

Neglect the partial pressure of air at the inlet to the condenser and state why it is reasonable to assume constant pressure throughout the condenser.

(16 marks)

6. A diesel engine produces 500 kW and is supplied with 0.031 kg/s of fuel with $Q_{net,v}$ of 42000kJ/kg and is known to be running at an AFR of 21. What is the overall efficiency of the engine?

If the exhaust gases at 300^{o}C flow into a Heat Recovery Steam Generator and produce superheated steam at 250^{o}C at a pressure of 15 bar, what mass flow of steam is expected to be produced if the pinch point is 10^{o}C and approach point is zero degrees. If the condenser condenses the steam at 30^{o}C and the steam turbine has an isentropic efficiency of 85%, what is the expected power produced from the steam turbine? For the hot gases in the HRSG use the c_p of 1.15kJ/kgK.

Draw the *Ts* diagrams for the combined cycle.

(20 marks)