UNIVERSITY OF MALTA
FACULTY OF ENGINEERING
B.ENG. (HONS.) COURSE
MECHANICAL ENGINEERING STREAM
YEAR IV – SEMESTER I
JANUARY/FEBRUARY 2013 SESSION OF EXAMINATIONS

MEC4011 – Power Plants **4th February, 2013**

0915 - 1215 hours

This paper contains <u>SIX</u> questions. You are to attempt <u>FIVE</u> questions.

Stationery: **Use of calculators is allowed**
Steam Tables
Sheets of useful equations

1. Draw a simple diagram of a surface condenser with separate condensate outlet and screened air outlet.

   A surface condenser is fitted with separate air and condensate outlets. 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. The condenser receives 20 000 kg/h of steam dry saturated at 36.2°C. At the condensate outlet the temperature is 34.6°C, and at the air extraction the temperature is 29°C. The volume of air plus vapour leaving the condenser is 3.8 m^3/min. Assuming constant pressure throughout the condenser and neglecting the partial pressure of the air at the inlet to the condenser.

   Calculate:

   (i) the mass of air removed per 10 000kg of steam

   (ii) the mass of steam condensed in the air cooler per minute

   (iii) the heat rejected to the cooling water

   (20 marks)

2. (a) Draw the velocity diagram for a reaction type steam turbine moving blade

If the diagram efficiency of the Parsons type (50% reaction) is given by:

$$\eta_d = \frac{2\left(\frac{C_b}{C_{ai}}\right)\left\{2\cos\alpha_i - \left(\frac{C_b}{C_{ai}}\right)\right\}}{1-\left(\frac{C_b}{C_{ai}}\right)^2 + 2\left(\frac{C_b}{C_{ai}}\right)\cos\alpha_i}$$

Show that the value of blade speed ratio for maximum diagram efficiency is given by:

$$\frac{C_b}{C_{ai}} = \cos\alpha_i$$

Note derivative of $(u'v - uv')/v^2$

(7 marks)

(b) An impulse reaction turbine of Parsons type has the nozzle exit angle 20° on one particular stage. The absolute inlet velocity of steam to the moving blades is 250 m/s. The blade velocity is 200 m/s.

Determine:
- (i) the moving blade angle at the inlet and exit
- (ii) the relative steam velocities at inlet and exit to the moving blades
- (iii) the enthalpy drop per kg of steam in the moving blades and in the complete stage
- (iv) the diagram power for 1 kg/s of steam flow
- (v) the diagram efficiency

(13 marks)

3. (a) Comment on blade speed ratio of simple impulse and velocity compounded turbines given the equations for optimal operation (see useful equations sheets).

(4 marks)

(b) The nozzles of the impulse stage of a turbine receive steam at 15 bar and 300°C and discharge it at 10 bar. The nozzle isentropic efficiency is 95 % and the nozzle angle is 20°. The blade speed is that required for maximum work, and the inlet angle of the blades is that required for entry of the steam without shock. The blade exit angle is 5° less than the inlet angle. The blade velocity coefficient is 0.9.

Draw a sketch of the velocity diagram

Calculate for a steam flow of 1350 kg/h:
- (i) the enthalpy drop in the nozzles
- (ii) the absolute velocity at the inlet to moving blades
- (iii) the blade speed
- (iv) the diagram power
- (v) the diagram efficiency.

(16 marks)

4. (a) For a spark ignition engine draw a typical curve of torque versus spark timing and explain MBT.

(4 marks)

(b) A V-8 four stroke petrol engine is required to give 186.5 kW at 4400rev/min. The brake thermal efficiency can be assumed to be 32 % at the compression ratio of 9/1. The air-fuel ratio is 12/1 and the volumetric efficiency at this speed is 69 %. If the stroke to bore ratio is 0.8, determine the engine displacement required and the dimensions of the bore and stroke. The $Q_{net,v}$ of the fuel is 44 200 kJ/kg, and the free air conditions are 1.013 bar and 15 °C. What is the torque and BMEP at this power and speed?

(16 marks)

5. (a) Draw a *pv* diagram for a diesel engine and define the compression ratio with reference to the *pv* diagram. How can the polytropic index during compression be determined from measured *pv* data.

(4 marks)

(b) A four-cylinder, four-stroke diesel engine has a bore of 212 mm and a stroke of 292mm. At full load at 720rev/min the BMEP is 5.93 bar and the specific fuel consumption is 0.226 kg/kWh. The air-fuel ratio as determined by exhaust gas analysis is 25/1. Calculate the brake thermal efficiency, the volumetric efficiency and torque of the engine. Atmospheric conditions are 1.01 bar and 15oC, and $Q_{net,v}$ of the fuel may be taken as 44 200kJ/kg.

(16 marks)

6. A gas turbine operates at a pressure ratio of 10, with the air inlet conditions being 20°C and $1x10^5$ Pa. The gas turbine intakes $500x10^3$ kg/h of fresh air. The gas turbine is fed with $9x10^3$ kg/h of fuel with calorific value $Q_{net,v}$ of 42 000 kJ/kg, and the resulting hot gases after the combustion chamber are at 1100°C. The hot gases are expanded in the turbine back to $1x10^5$ Pa and result with a temperature of 540°C. Assuming that all the heat obtained from the calorific value of the fuel is transferred fully to the hot gases, and that the c_p and γ for air are 1.005 kJ/kgK and 1.4, while for the combustion and expansion processes hot gases c_p and γ are 1.15 kJ/kgK and 1.333 respectively.

(a) Draw the cycle on a T-s diagram.

(b) Calculate
(i) the compressor work
(ii) the turbine gross work
(iii) overall gas turbine efficiency

(c) If the exhaust gases at 540°C flow into a Heat Recovery Steam Generator and produce superheated steam at 450°C at a pressure of 40 Bar, what mass flow of steam is expected to be produced if the pinch point is 10°C and approach point is zero degrees. If the condenser condenses the steam at 30°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.

(20 marks)