Menofia University		Subject: MPE 519 Gas Turbines
Faculty of Engineering		Date: 19/8/2020
Department of Mech. Power Eng.		Time: From 10 to 13
Postgraduate Diploma		Total marks: 100

Answer the following questions with assuming any missing data

Question 1 — 25 marks

a) Define: thermal efficiency, propulsive efficiency, regenerator effectiveness, loading coefficient, back work ratio **5 marks**

b) Prove that; for an axial compressor stage, the degree of reaction R can be calculated from the following equation;

$$R = \frac{1}{2}\phi(\tan\beta_1 + \tan\beta_2)$$

Where β_1 and β_2 are the inlet and exit flow angle
Φ is flow coefficient. **8 marks**

c) Explain what is the effect of high inlet temperature on specific power output, specific thrust, plant and turbine stage efficiencies? **5 marks**

d) Draw velocity triangles at the entry and exit for an axial compressor stages with following degree of reaction:

$$R = \frac{1}{2}, \qquad R = 1$$

7 marks

Question 2 — 25 marks

a) What are the most important properties which the high temperature blade material must have? **5 marks**

b) Describe various methods of cooling gas turbine blades? **5 marks**

c) Starting from the fundamental equations of heat transfer, prove that the variation of the coolant and blade metal temperature along the blade height are given by

$$\frac{T_C - T_{ch}}{T_g - T_{ch}} = 1 - e^{-C_1 z}$$

Where T_g is the gas temperature
T_c is the coolant temperature
T_{ch} is the coolant temperature at hub
Z is the blade height **5 marks**

d) A turboprop engine consists of a diffuser, compressor, combustor, turbine, and nozzle. The turbine drives a propeller as well as the compressor. Air enters the diffuser with a volumetric flow rate of 83.7 m^3/s at 40 kPa, 240 K, and a velocity of 180 m/s, and decelerates essentially to zero velocity. The compressor pressure ratio is 10 and the compressor has an isentropic efficiency of 85%. The turbine inlet temperature is 1140 K, and its isentropic efficiency is 85%. The turbine exit pressure is 50 kPa. Flow through the diffuser and nozzle is isentropic. Using an air-standard analysis, determine

i- The power delivered to the propeller, in MW.

ii- The nozzle exit area, in m^2.

Neglect kinetic energy except at the diffuser inlet and the nozzle exit. **10 marks**

Question: 3 **25 marks**

a) What is stalling in axial flow compressors? How is it developed? Describe briefly. **5 marks**

b) An axial compressor stage has a mean diameter of 60 cm and runs at 15000 rpm. If the actual temperature rise and pressure ratio developed are 30°C and 1.4 respectively, determine::

i- The power required to derive the compressor while delivering 57 kg/s of air, assume mechanical efficiency of 86% and an initial temperature of 35°C.

ii- The stage loading coefficient,

iii- The stage efficiency, and

iv- The degree of reaction if the temperature at the rotor exit is 55°C. **20 marks**

Question: 4 **25 marks**

a) What are the various methods employed for improving the efficiency and output of a constant pressure gas turbine plant? **5 marks**

b) A gas turbine power plant has an output of 100 MW at the generator terminals. Its data is given below:

Air compressor inlet pressure and temperature $p_1 = 1.013$ bar, $T_1 = 310$ K

Compressor pressure ratio = 8.0, efficiency $\eta_c = 0.85$,

Turbine inlet temperature =1350 K, efficiency $\eta_t = 0.9$

Turbine inlet pressure = 098 x compressor exit pressure

Turbine exit pressure =1.02 bar.

Calorific value of the fuel, Q_f =40 MJ/kg

Combustion efficiency, $\eta_B = 0.98$,

Mechanical efficiency, $\eta_m = 0.97$,

Generator efficiency, $\eta_G = 0.98$

Take $\gamma = 1.33$, R = 0.287 kJ/kg K for the gas.

Determine:

i- Gas flow rate,

ii- Fuel-air ratio,

iii- Air flow rate,

iv- Thermal efficiency of the power plant, and

v- Overall efficiency **20 marks**

With our best wishes