

**University of Nottingham**  
**Department of Mechanical, Materials and Manufacturing engineering**

**Thermofluids 3**

Self Assessment Exercise Sheet – Gas Turbines

1. Determine the cycle efficiency, the specific work output, the exhaust temperature and the work ratio for the following cycles:
  - a) Simple open cycle with pressure ratio of 10 and maximum temperature of 1100K.
  - b) Heat exchange (recuperation) cycle with heat exchanger effectiveness of 0.9, pressure ratio of 6 and maximum temperature of 1100 K.
  - c) Cycle as in (b) but with compressor split into two stages, each with a pressure ratio of 2.44, and intercooling of air at outlet of from the first stage to 45°C before entering the second stage of the compressor. The effectiveness of the heat exchanger is still 0.9 and the maximum temperature 1100K.

Assume in each case that: the isentropic efficiency of the compressor is 85%, the isentropic efficiency of the turbine is 90%, the working fluid is air throughout with  $c_p = 1.005 \text{ kJ/kgK}$  and  $\gamma = 1.4$ , the air inlet temperature is 15°C and inlet pressure is 1 bar. Neglect any other losses.

[a] 32.6%, 162.8 kJ/kg, 349.7°C, 0.339, b) 41.2%, 171 kJ/kg, 260°C, 0.429  
[(c) 44.7%, 190.4 kJ/kg, 181.4°C, 0.48 ]

2. A Rolls Royce 'Avon' gas turbine is used for electricity generation. The turbine is in two stages; the high pressure stage drives only the compressor and the low pressure stage drives the generator. The turbine inlet temperature is 1150K, the pressure ratio is 10 and the air mass flow rate is 80 kg/s. Calculate the output of the electricity generator when the inlet air temperature is 15°C, assuming zero pressure loss during combustion and that there is no change in mass flow rate due to fuel addition. Isentropic efficiencies are:

Compressor	85%
HP turbine	88%
LP turbine	90%

The generator efficiency is 91%.

In compressor assume  $c_p = 1.005 \text{ kJ/kgK}$  and  $\gamma = 1.4$

In turbines assume  $c_p = 1.15 \text{ kJ/kgK}$  and  $\gamma = 1.333$

[ 15.0 MW ]

3. A gas turbine generator has an electricity output of 226.5 MW. The pressure ratio in the compressor is 15 and the turbine inlet temperature is 1290°C. The polytropic efficiency of both the compressor and turbine is 85%. There are pressure losses of 0.5 bar in the combustion chamber, 0.01 bar in the inlet to the compressor and 0.02 bar in the exhaust ducting. The combined mechanical and electrical generation efficiency of the turbine, gearbox and generator is 96%. The atmospheric conditions are 1.013 bar pressure and 15°C temperature. The net calorific value of the fuel is 42 MJ/kg. Allow for additional mass flow in the turbine due to the fuel but neglect any air bleed from the compressor for cooling. In compressor assume  $c_p = 1.005 \text{ kJ/kgK}$  and  $\gamma = 1.4$ . In turbine assume  $c_p = 1.15 \text{ kJ/kgK}$  and  $\gamma = 1.333$

Calculate the air mass flow rate, the fuel mass flow rate and the overall electricity generation efficiency.

[ 650.3 kg/s, 16.6 kg/s, 32.5% ]