GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY
Faculty of Engineering
Department of Mechanical Engineering

BSc Engineering (Hons) Degree
Semester 2 Examination – November 2022
(Intake 39- AE, CE, EE, ET, MC, ME, MR, NA)

ME 1202 – FUNDAMENTALS OF THERMODYNAMICS

Time allowed: 3 hours 21 November 2022

ADDITIONAL MATERIAL PROVIDED

Gas Constant, R = 0.287 kJ/kgK,
C_p = 1.005 kJ/kgK and C_v = 0.718 kJ/kgK for air

INSTRUCTIONS TO CANDIDATES

This paper contains 5 questions on 5 pages

Answer <u>ALL</u> questions

This is a closed book examination

This examination accounts for 70% of the module assessment. A total maximum mark obtainable is 100. The marks assigned for each question and parts thereof are indicated in square brackets

If you have any doubt as to the interpretation of the wordings of a question, make your own decision, but clearly state it on the script

Assume reasonable values for any data not given in or provided with the question paper, clearly make such assumptions made in the script

All examinations are conducted under the rules and regulations of the KDU

Question 01

a. Sketch **P-V diagrams** for the following Non – Flow processes with usual notations.

i. Isochoric process
ii. Isothermal process
iii. Adiabatic process
iv. Isobaric process **(06 Marks)**

b. A cylinder contains 0.1 kg of Nitrogen gas with the initial volume of 0.1 m^3 and pressure in the cylinder maintained at 1.15 bar. Heat transfer occurs until the volume is reduced to 75% of initial volume, compute the following;

i.	Initial temperature of Nitrogen gas	**(04 Marks)**
ii.	Final temperature	**(03 Marks)**
iii.	Work done by the gas	**(02 Marks)**
iv.	Change in internal energy	**(02 Marks)**
v.	Amount of heat transferred and direction	**(03 Marks)**

Take C_p is 1.05 kJ/kgK , C_v is 0.745 kJ/kgK nad molecular mass is 28 for Nitrogen gas.

Question 02

a. State the **Steady Flow Energy Equation** with usual notations. **(03 Marks)**

b. Apply the above equation to derive an expression for the work output of a horizontally placed gas turbine with usual notations. Clearly state the assumptions made.

(04 Marks)

c. Air enters a heat exchanger at 290 K and 30 m/s velocity and its temperature raised to 1100 K at the exit. Subsequently, the heated air enters a turbine with the same velocity and its expansion continues until the temperature drops to 900 K. Air exits from the turbine at 45 m/s and further expansion occurs in a nozzle to falls down its temperature up to 790 K. If the mass flow rate of air is 2 kg/s, compute the following;

i. Rate of heat transfer to air in the heat exchanger **(05 Marks)**

ii. Power output from the turbine **(04 Marks)**

iii. Velocity at exit of the nozzle **(04 Marks)**

Question 03

a. Define the **Clausius statement** related to the Second Law of Thermodynamics briefly. **(03 Marks)**

b. Prove that the Coefficient of performance (CoP) of the heat pump as the following expression with usual notations.

$$(CoP)_{HP} = (CoP)_R + 1$$

(03 Marks)

c. A heat engine operating between two reservoirs at 1000 k and 300 K is used to drive a heat pump which extracts heat from the reservoir at 300 K, at a rate of twice that the heat engine rejects heat to it. If the efficiency of the engine is 40% of the maximum possible and the coefficient of performance of the heat pump is 50% of maximum possible. Compute the following;

i. Temperature of the reservoir that heat pump rejects heat **(10 Marks)**

ii. Rate of heat rejection from the heat pump if the rate of heat supply to the engine is 50 kW **(04 Marks)**

Question 04

a. Derive the following expression for the change of entropy for a perfect gas undergoing a non-flow isobaric process with usual notations.

$$S_1 - S_2 = C_p \ln \frac{T_2}{T_1}$$

(03 Marks)

b. A reversible heat engine connects to three sources at 400 K, 300 K and 200 K respectively. The heat engine draws 1200 kJ from source at 400 K and produces 200 kJ of work. Compute the following clearly stating the assumptions made;

i. The amount and directions of heat interactions with the other heat sources **(12 Marks)**

ii. Change of entropy due to each of heat interactions with the heat engine **(03 Marks)**

iii. Change of entropy of the cycle **(02 Marks)**

Question 05

a. Derive the following expression for an ideal air-standard Diesel cycle relating the compression ratio and cut off ratio with usual notations.

$$\eta = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}\right]$$

(06 Marks)

b. In an air standard Diesel cycle, the volume ratio of compression and expansion for a Diesel engine as measured from an indicator diagram are 15.3 and 7.5 respectively. The pressure and temperature at the initial state of the compression are 01 bar and 27 °C. Assuming an ideal engine, compute the following;

i. Mean effective pressure **(11 Marks)**

ii. Ratio of maximum pressure to mean effective pressure **(01 Marks)**

iii. Cycle efficiency **(02 Marks)**

For air, Cp = 1.005 kJ/kgK, Cv = 0.7 kJ/kgK and γ = 1.4

End of question paper