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**UNIVERSITY EXAMINATIONS 2024/2025**

SECOND YEAR FIRST SEMESTER EXAMINATION FOR DEGREE OF BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING

**EMT 3203: APPLIED THERMODYNAMICS I**

**DATE: JANUARY 2025** **TIME: 2 HOURS**

**INSTRUCTIONS:** Answer Question ONE and any other TWO questions.
You must have a clean copy of 'steam tables ' for this examination.

**QUESTION ONE (30 MARKS)**

a) Define the following terms:
   i. System (1 mark)
   ii. Surroundings (1 mark)

b) State the first law of thermodynamics (2 marks)

c) State the ideal gas equation (1 mark)

d) With the aid of a well labelled diagram, show that the Carnot efficiency is given by:

$$\eta carnot = 1 - \frac{T_2}{T_1}$$

Where $T_1$ =source temperature
$T_2$ =Sink temperature (5 marks)

e) The relative molecular weight of a certain perfect gas was established in an experiment to be 54 and the value of $\gamma$ to be 1.26. determine:
   i. The specific gas constant R, (l marks)
   ii. The specific heat capacities if the gas at constant pressure ($c_p$) and at constant c) volume ($c_v$). (4 marks)

f) Using neat sketches illustrate a reversible constant temperature (isothermal process) on a p-v diagram when the working fluid is:
   i. A perfect gas (3 marks)

ii. Steam (3 marks)

g) I kg of steam at 20 bar dryness fraction 0.9 is heated reversibly at constant pressure to a temperature of 300 $^0$ C.

i. Sketch the cycle on a T-s diagram indicating the area that represents the heat flow, (2 marks)

ii. Calculate the change in entropy and the heat supplied. (4 marks)

h) A certain fluid at 15 bar is contained in a cylinder behind a piston, the initial volume being 0.06 $m^3$ . Determine the work done by the fluid when it expands reversibly according to a law pV= C to a final volume of 0.12 $m^3$ (3 marks)

**QUESTION TWO (15 MARKS)**

a) In a gas turbine unit, gas flows through the unit at 15 kg/s and the unit develops 12 kW. The velocities of the gases at the inlet port and exhaust pipe are 54 m/s and 137 m/s respectively while the specific enthalpy of the gases at entry and exit are 1080 kJ/kg and 340 kJ/kg. Calculate the heat rejected by the turbine. (4 marks)

b) A unit mass of fluid at a pressure of 3 bar and with a specific volume of 0.15 $m^3$/kg is contained in a cylinder behind a piston. The fluid expands reversibly to a pressure of 0.6 bar according to a law $pv^2 = c$, where c is a constant:

i. Sketch the expansion process on a p-v diagram. (2 marks)

ii. Calculate the work done during the process. (4 marks)

c) A vessel of volume 0.27 $m^3$ contains nitrogen at 1.013 bar and 15 $^0$ C. If 0.36 kg of nitrogen is now introduced into the vessel; calculate the new pressure in the vessel when the initial conditions are restored. Take the mass of nitrogen to be 28 kg/Kmol and assume it is a perfect gas. (5 marks)

**QUESTION THREE (15 MARKS)**

a) State the second law of thermodynamics. (3 marks)

b) Calculate the dryness fraction of steam at 60 bar if its entropy is 5.580 kJ/kgK. (4 marks)

c) Dry saturated steam at 100 bar expands reversibly at constant temperature to a pressure of 10 bar.

i. Sketch the process on a T-s diagram and indicate the area that represents the heat flow. (3 marks)

ii. Calculate the heat supplied per kilogram of steam during the process. (5 marks)

**QUESTION FOUR (15 MARKS)**

a) Using neat sketch, show that the thermal efficiency of a constant volume air standard cycle is given by the expression:

$$\eta = 1 - \frac{1}{r_v^{\gamma-1}}$$

Where $r_v$ = compression ratio

$\gamma$ = index of expansion (6 marks)

b) A three-cylinder gasoline engine has a displacement of 1200 $cm^3$ while the clearance volume of each cylinder is 48 $cm^{3.}$ Calculate the air standard efficiency of the engine. Determine also the mean effective pressure if the induction conditions are 1 bar and 25 $^0$C and the maximum cycle temperature is $1350^0$ C. (9 marks)

**QUESTION FIVE (15 MARKS)**

a) Determine the entropy of steam at 382 bar and $569^0$ C. (6 marks)

b) 0.032 $m^3$ of nitrogen (molar mass 28 kg/kmol) contained in a cylinder behind a piston is initially at 1.05 bar and $15^0$ C. The gas is compressed isothermally and reversibly until the pressure is 4.2 bar.

i. Sketch the process on a p-v and T-s diagram, (4 marks)

ii. Calculate the change in entropy for the mass of gas involved. (5 marks)