

Code : 021307

(2)

B.Tech 3rd Semester Exam., 2018

THERMODYNAMICS

Time : 3 hours

Full Marks : 70

Instructions :

- (i) The marks are indicated in the right-hand margin.
- (ii) There are **NINE** questions in this paper.
- (iii) Attempt **FIVE** questions in all.
- (iv) Question No. 1 is compulsory.

1. Choose the correct option of the following
(any seven) : $2 \times 7 = 14$

(a) Which of the following are intensive properties?

1. Kinetic energy
2. Specific enthalpy
3. Pressure
4. Entropy

Select the correct option using the code given below :

- (i) 1 and 3
- (ii) 2 and 3
- (iii) 1, 3 and 4
- (iv) 2 and 4

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(Turn Over)

(b) Ice kept in a well-insulated thermo-flask is an example of which system?

- (i) Closed system
- (ii) Isolated system
- (iii) Open system
- (iv) Non-flow adiabatic system

(c) A gas contained in a cylinder is compressed, the work required for compression being 5000 kJ. During the process, heat interaction of 2000 kJ causes the surroundings to be heated. The change in internal energy of the gas during the process is

- (i) -7000 kJ
- (ii) -3000 kJ
- (iii) +3000 kJ
- (iv) +7000 kJ

(d) A reversible heat engine operating between hot and cold reservoirs delivers a work output of 54 kJ while it rejects a heat of 66 kJ. The efficiency of this engine is

- (i) 0.45
- (ii) 0.66
- (iii) 0.75
- (iv) 0.82

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- (e) A reversible engine operates between temperatures 900 K and T_2 ($T_2 < 900$ K), and another reversible engine between T_2 and 400 K ($T_2 > 400$ K) in series. What is the value of T_2 if work outputs of both the engines are equal?

- (i) 600 K
- (ii) 625 K
- (iii) 650 K
- (iv) 675 K

- (f) In a cyclic heat engine operating between a source temperature of 600 °C and a sink temperature of 20 °C, the least rate of heat rejection per kW net output of the engine is

- (i) 0.460 kW
- (ii) 0.505 kW
- (iii) 0.588 kW
- (iv) 0.650 kW

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- (g) If a closed system is undergoing an irreversible process, the entropy of the system

- (i) must increase
- (ii) always remains constant
- (iii) must decrease
- (iv) can increase, decrease or remain constant

- (h) A Carnot engine operates between 327 °C and 27 °C. If the engine produces 300 kJ of work, what is the entropy change during heat addition?

- (i) 0.5 kJ/K
- (ii) 1.0 kJ/K
- (iii) 1.5 kJ/K
- (iv) 2.0 kJ/K

- (i) A gas having a negative Joule-Thompson coefficient ($\mu < 0$), when throttled, will

- (i) become cooler
- (ii) become warmer
- (iii) remain at the same temperature
- (iv) either be cooler or warmer depending on the type of gas

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- (i) Which one of the following represents the condensation of a mixture of saturated liquid and saturated vapour on the enthalpy-entropy diagram?

- (i) A horizontal line
- (ii) An inclined line of constant slope
- (iii) A vertical line
- (iv) A curved line

2. (a) Convert the following readings of pressure to kPa, assuming that the barometer reads 760 mmHg :

- (i) 90 cmHg gauge
- (ii) 40 cm Hg vacuum
- (iii) 1.2 m H₂O gauge
- (iv) 3.1 bar

- (b) The resistance of a platinum wire is found to be 11,000 ohms at the ice point, 15.247 ohms at the steam point, and 28.887 ohms at the sulphur point. Find the constants A and B in the equation

$$R = R_0(1 + At + Bt^2)$$

And plot R against t in the range 0 to 660 °C.

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(Turn Over)

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3. (a) Show that heat and work are path functions and not a property. A single-cylinder, double-acting, reciprocating water pump has an indicator diagram which is a rectangle 0.075 m long and 0.05 m high. The indicator spring constant is 147 MPa per m. The pump runs at 50 r.p.m. The pump cylinder diameter is 0.15 m and the piston stroke is 0.20 m. Find the rate in kW at which the piston does work on the water.

- (b) State the first law of thermodynamics for a closed system undergoing a change of state. A gas of mass 1.5 kg undergoes a quasi-static expansion which follows a relationship $p = a + bV$, where a and b are constants. The initial and final pressures are 1000 kPa and 200 kPa respectively and the corresponding volumes are 0.20 m³ and 1.20 m³. The specific internal energy of the gas is given by the relation $u = 1.5 pv - 85$ kJ/kg, where p is the kPa and v is in m³/kg. Calculate the net heat transfer and the maximum internal energy of the gas attained during expansion.

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4. (a) Derive the steady flow energy equation (SFEE). Under what conditions the SFEE does reduce to Euler's equation? 7

- (b) A turbo compressor delivers $2.33 \text{ m}^3/\text{s}$ at 0.276 MPa , 43°C which is heated at this pressure to 430°C and finally expanded in a turbine which delivers 1860 kW . During the expansion, there is a heat transfer of 0.09 MJ/s to the surroundings. Calculate the turbine exhaust temperature if changes in kinetic and potential energy are negligible. 7

5. (a) A heat pump working on the Carnot cycle takes in heat from a reservoir at 5°C and delivers heat to a reservoir at 60°C . The heat pump is driven by a reversible heat engine which takes in heat from a reservoir at 840°C and rejects heat to a reservoir at 60°C . The reversible heat engine also drives a machine that absorbs 30 kW . If the heat pump extracts 17 kJ/s from the 5°C reservoir, determine—

- (i) the rate of heat supply from the 840°C source;
(ii) the rate of heat rejection to the 60°C sink. 7

- (b) What do you understand by exergy and energy? In a steam generator, water is evaporated at 260°C , while the combustion gas ($c_p = 1.08 \text{ kJ/kg K}$) is cooled from 1300°C to 320°C . The surroundings are at 30°C . Determine the loss in available energy due to the above heat transfer per kg of water evaporated (Latent heat of vaporization of water at $260^\circ\text{C} = 1662.5 \text{ kJ/kg}$).

6. (a) Give the criteria of reversibility, irreversibility and impossibility of a thermodynamic cycle. Two vessels, A and B, each of volume 3 m^3 may be connected by a tube of negligible volume. Vessel A contains air at 0.7 MPa , 95°C , while vessel B contains air at 0.35 MPa , 205°C . Find the change of entropy when A is connected to B by working from the first principles and assuming the mixing to be complete and adiabatic. Take $C_p = 1.005$ and $C_v = 0.718 \text{ kJ/kg-K}$ and assume the specific heats to be constant. Also assume for air $p\nu = 0.287 T$, where p is the pressure in kPa, ν is the specific volume in m^3/kg , and T is the temperature in K.

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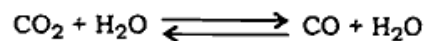
- (b) Show that the adiabatic mixing of two fluids is irreversible. Each of three identical bodies satisfies the equation $U = CT$, where C is the heat capacity of each of the bodies. Their initial temperatures are 200 K, 250 K, and 540 K. If $C = 8.4 \text{ kJ/K}$, what is the maximum amount of work that can be extracted in a process in which these bodies are brought to a final common temperature? 7
7. (a) Explain why the specific heat of a saturated vapour may be negative. 4
- (b) Explain, with suitable example, what is a pure substance? Draw the labelled phase equilibrium diagram for table salt on p - v , T - s and h - s coordinates. A large insulated vessel is divided into two chambers, one containing 5 kg of dry saturated steam at 0.2 MPa and the other 10 kg of steam, 0.8 quality at 0.5 MPa. If the partition between the chambers is removed and the steam is mixed thoroughly and allowed to settle, find the final pressure, steam quality and entropy change in the process. 10

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8. (a) With the help of neat sketch, differentiate between the working of Otto and Diesel cycle. 4
- (b) A geothermal power plant utilizes steam produced by natural means underground. Steam wells are drilled to tap this steam supply which is available at 4.5 bar and 175 °C. The steam leaves the turbine at 100 mmHg absolute pressure. The turbine isentropic efficiency is 0.75. Calculate the efficiency of the plant. If the unit produces 12.5 MW, what is the steam flow rate? 10
9. (a) What is the difference between specific and relative humidity? When does they become maximum? 4
- (b) Atmospheric air at dry bulb temperature of 15 °C enters a heating coil whose surface temperature is maintained at 40 °C. The air leaves the heating coil at 25 °C. What will be the by-pass factor of the heating coil? 5

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(c) For chemical reaction



The equilibrium value of the degree of reaction at 1200 K is 0.56. Determine the equilibrium constant and the Gibbs function change.

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