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INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Department of Mechanical Engineering

Date : Time : **2** hours Full Marks : **100** No. of students :

Mid-Sem. 2016 Sub. name: **Applied Thermo-Fluids-I** Sub.No.: **ME40701**

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<u>All questions in Part-A and Part-B are compulsory.</u>

Wherever necessary, make suitable assumptions and state them clearly

Part-A (Internal Combustion Engines)

1) By a suitable diagram, identify the following on the diagram itself: BDC, TDC, bore, stroke length, crank, connecting rod, small end, big end. **(2x8=16)**

2) Draw the actual indicator diagram of a four-stroke SI engine on the plot of air standard cycle itself and explain the difference on the processes. Draw the valve timing diagram of the four strokes and explain. **(7+7=14)**

3) A four cylinder in-line internal combustion engine working on a 4 stroke Diesel cycle has a stroke volume 1200 cc. At the beginning of the compression stroke, the pressure and temperature are 1 bar and 27^{0}C respectively. The compression ratio is 18 and the cut-off is 20% of the swept volume. Considering air-standard cycle,

- **a)** Draw the cycle is *P-v* and *T-s* diagram.
- **b)** Calculate the compression work, expansion work and the heat addition in kJ/kg.
- **c)** Thus find out the efficiency of the engine.
- **d)** Calculate the power of the engine if it runs at 3000 rpm.

Consider air-standard cycle for the calculation. c_p=1.005 kJ/kg-K, c_v=0.718 kJ/kg-K **(4+9+2+5=20)**

Part-B (Refrigeration & Air conditioning)

(1 Ton of Refrigeration (TR) = 3.517 kW)

4a) With the help of suitable diagrams and equations explain why standard vapour compression refrigeration cycles normally employ *isenthalpic expansion* process instead of *isentropic expansion*. Under what conditions use of isentropic expansion may become economically attractive? **(5+3 = 8)**

4b) A single stage saturated (SSS) vapour compression refrigeration cycle, which uses ammonia (R717) as refrigerant operates between an evaporator temperature of **–36°C** and a condensing temperature of **38°C**. a) Draw the SSS cycle on temperature-entropy diagram and indicate the throttling and superheat losses on the diagram, b) Find COP and cycle efficiency of this cycle, c) Find the required refrigerant flow rates (in kg/s) for the SSS cycle and a reversible cycle operating between same evaporator and condensing temperatures, if both the cycles have to produce a refrigeration capacity of **100 TR**?

Given: throttling and de-superheating losses of the SSS cycle are **47.1 kJ/kg** and **60.91 kJ/kg**, respectively, and the refrigeration effect of the reversible refrigeration cycle is **1080 kJ/kg**. **(2+6+2 = 10)**

5a) IIT Kharagpur campus has installed air conditioning (AC) capacity of **6000 TR.** The annual electrical energy consumption due to air conditioning is **15000 MWh** with an average AC usage of **12 hours per day** for **180 days.** The average air conditioned space temperature is **25°C** and that of ambient heat sink temperature is **35°C**. From the data given a) estimate the rate at which the air conditioning systems in our campus generate entropy (in kW/K), and b) What would be the annual savings in rupees, if through design improvements the entropy generation rate due to AC systems is reduced by **10 %**? The cost of electrical energy is **Rs. 8 per kWh**. State clearly the assumptions made while arriving at the above answers. (2+6+2 = 10)

5b) Draw **temperature-entropy** and **pressure-enthalpy** diagrams for the following refrigeration cycles: **(2x4 = 8)**

i) Carnot Refrigeration Cycle
ii) Ideal, single stage saturated, vapour compression refrigeration cycle
iii) Ideal, single stage cycle with liquid-to-suction heat exchanger (assume saturated condition at condenser and evaporator exit)
iv) Actual, single stage vapour compression cycle with adiabatic, but irreversible compression and pressure drop across evaporator (assume saturated condition at condenser and evaporator exit)

6a) Write the chemical formulae of the following refrigerants: **(1 x 6 = 6)**

i) R12 ii) R290 iii) R134a iv) R717 v) R22 vi) R744

6b) The cylinder of the reciprocating compressor of a domestic refrigerator has a stroke length of ***1.5 cm*** and an inner diameter of ***2.5 cm***. The electrical motor which drives the compressor runs at ***2900 RPM***. The refrigerator operates at an evaporator temperature of ***–23°C*** and a condensing temperature of ***54°C***. The **refrigeration effect** and ***isentropic work of compression*** under the operating conditions are ***123.9 kJ/kg*** and ***112.7 kJ/kg***, respectively. Use the following equations for calculating the saturation pressure (p_{sat}) of the refrigerant, the volumetric efficiency (η_{vol}) and isentropic efficiency (η_{is}) of the compressor. (r_p is the ratio of condenser to evaporator pressure, p_c/p_e). Assume that the refrigerant vapour at inlet to compressor is at ***32°C***, and the vapour behaves as an ideal gas with a gas constant of ***0.08148 kJ/kg.K***. From the given data, find a) Refrigeration capacity (in W), and b) Power input to compressor (in W). (4 + 4 = 8)

$$p_{sat} = \exp^{\left(14.41 - \frac{2094}{T - 33.06}\right)} \quad where \ p_{sat} \ is \ in \ kPa \ and \ T \ is \ in \ K$$

$$\text{Volumetric efficiency of compressor}, \eta_{vol} = 0.95 - 0.1 r_p^{0.5}$$

$$\text{Isentropic efficiency of compressor}, \eta_{is} = 0.85 - 0.05 r_p^{0.55}$$

End of the question paper