

CSM – 55/20
Mechanical Engineering
Paper – II

Time : 3 hours

Full Marks : 300

The figures in the right-hand margin indicate marks.

*Candidates should attempt Q. No. 1 from
Section – A and Q. No. 5 from Section – B
which are compulsory and any three of
the remaining questions, selecting
at least one from each Section.*

SECTION – A

1. Answer any three of the following :

- (a) Calculate the non-flow work done for a gas which expands from initial pressure 5 bar and volume 4 m^3 to the final volume 20 m^3 under the following reversible processes. Show the process on p-v diagram : 20

(i) $p = c$

(ii) $v = C$

(iii) $pv = C$

(iv) $pv^\gamma = C$, where, $\gamma = 1.4$

(v) $pv^r = C$, where, $r = 1.25$

comment on the results.

- (b) Compare the efficiencies of ideal Atkinson cycle and Otto cycle for a compression ratio of 6. The condition of air before isentropic compression is 1 bar and 27°C . The maximum pressure for both the cycles is 20 bar.

- (c) An aircraft is cruising with a speed of 900 km/hr at an altitude of 11000 m where the ambient conditions are 0.30 bar and -30°C . Assuming the compression ratio 5, cabin pressure 0.80 bar and air leaving the cabin at 27°C , calculate the power for pressurization and refrigeration and COP. The flow rate through the system is 1.0 kg/s.

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- (d) What are the unique features of high pressure boilers ? Also mention five advantages of high pressure boilers. 20

2. (a) What do you mean by availability of a closed system ? Derive an expression for availability of a closed system. 30

- (b) A four-stroke cycle gas engine has a bore of 20 cm and a stroke of 40 cm. The compression ratio is 6. In a test on the engine the indicated mean effective pressure is 5 bar, the air to gas ratio is 6 : 1 and the calorific value of the gas is 12 MJ/m^3 at NTP. At the beginning of the compression stroke the temperature is 77°C and pressure is 0.98 bar. Calculate : 30

- (i) The indicated power
- (ii) The thermal efficiency
- (iii) The relative efficiency of the engine at 250 rpm

Neglect the residual gases.

3. (a) Twenty people attended a Cocktail party in a small room of size $6\text{m} \times 8\text{m}$ and has a 3m ceiling. Each person gives up about 400 KJ of heat per hour. Assuming that the room is completely sealed off and insulated, calculate the air temperature rise occurring within 30 minutes.

Assume,

$$C_v \text{ of air} = 0.718 \text{ KJ/Kg}$$

$$R = 0.287 \text{ KJ/Kg-K}$$

and each person occupies a volume of 0.07 m^3 .

Comment on the result. 30

- (b) A centrifugal compressor has an impeller with 21 radial vanes, a vaneless diffuser and no inlet guide vanes. At inlet the stagnation pressure is 100 KPa abs. and the stagnation temperature is 300K : 30

- (i) Given that the mass flow rate is 2.3 kg/s , the impeller tip speed is 500 m/s and the mechanical efficiency is 96% ,

determine the driving power. The slip

factor is given by, $\sigma = 1 - \frac{0.63\pi}{z}$.

(ii) Determine the total and static pressures at diffuser exit when the velocity at that position is 100 m/s. Overall efficiency of the compressor is 82%.

(iii) The reaction is 0.5, the absolute flow speed at impeller entry is 150 m/s and diffuser efficiency is 84%. Determine the total and static pressures, absolute mach number, and the radial component of velocity at impeller exit.

4. (a) Explain co-efficient of compressibility of oil.

In a diesel fuel injection pump the volume of the fuel in the pump barrel before the commencement of the effective stroke is

7 c.c. The fuel line from the pump to injector is 3 mm in diameter and 700 mm long and the fuel in the injection valve is 3 c.c.

Determine :

- (i) The pump displacement necessary to deliver 0.15 c.c. of fuel at a pressure of 200 bar. Assume a sump (atmospheric) pressure of 1 bar.
- (ii) The effective stroke of the plunger if the diameter of the plunger is 8 mm.

Take the coefficient of compressibility of oil (78.8×10^{-6}) when pressures are in atmospheres. 30

- (b) What are Psychrometers ? Briefly explain the following with neat sketches : 30

- (i) Modified psychrometer
- (ii) Aspirated psychrometer

SECTION – B

5. Answer any three of the following :

- (a) What is Van der Waals equation of state ?
What is the significance of the various constants involved in this equation ? Are there any limitations ? If yes, explain briefly.

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- (b) For a power station, the yearly load duration curve is a straight line from 30000 KW to 4000 KW. To meet the load the turbo-generator system is in use. The capacity of two generators is 15000 KW each and the third is rated at 5000 KW. Calculate the following :

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- (i) Load factor
- (ii) Capacity factor
- (iii) Maximum demand

- (c) Discuss the suitability of the following fuels in diesel engines :

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- (i) Alcohols

(ii) Vegetable oils

(iii) Biogas

(d) Explain Gibbs free energy. What is its physical significance ? 20

6. (a) A reciprocating air compressor installed in a factory takes in air at 1 bar and 20°C and delivers at 6 bar. Determine the workdone, heat transfer and change in internal energy per kg of air compressed if the compression process follows : 30

(i) Isothermal

(ii) Reversible adiabatic

(iii) Polytropic $p v^{1.25} = \text{constant}$

Assume the changes in potential and kinetic energies as nil.

(b) An axial turbine stage has the following data :

Nozzle exit air angle $\alpha_2 = 70^{\circ}$

Rotor blade air angles $\beta_2 = \beta_3 = 54^{\circ}$

Mean diameter of the blade rings = 1m

Speed = 3000 rpm

Aspect ratio of the blade rows = 1.0

Determine :

- (i) The total-to-total efficiency
- (ii) The total-to-static efficiency 30

7. (a) Discuss the effect of the following engine variables on flame propagation : 30

- (i) Fuel-air ratio
- (ii) Compression ratio
- (iii) Turbulence
- (iv) Engine speed
- (v) Engine load and size

(b) (i) The ambient air temperatures during summer and winter in a particular locality are 45°C and 15°C respectively. Find the values of Carnot COP for an air conditioner for cooling and heating, corresponding to refrigeration (b)

temperatures of 5°C for summer and heating temperature of 55°C for winter. Assume suitable temperature differences in the exchanger that exchanges heat with the surroundings.

- (ii) If water from the cooling tower at 30°C is used as a cooling medium with 3°C temperature differential for air-conditioning in summer, what will be the Carnot COP for cooling ?
- (iii) Find the theoretical power consumption per ton of refrigeration in each case. Assume no increase in the temperature of the surrounding air or water. Suitably assume any data if missing. Comment on the result.
- (iv) Also mention why in a refrigeration plant as a cooling medium, water is preferred to air.

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8. (a) A compressor has the following data :

Air flow rate = 1.5778 kg/sec

Pressure ratio = 1.6

Rational speed = 54000 rpm

Efficiency = 85%

State of air at entry :

$$P_{01} = 1.008 \text{ bar}$$

$$T_{01} = 300 \text{ K}$$

$$C_p = 1.009 \text{ KJ/Kg-K}$$

- (i) Determine the power required to drive this compressor.
- (ii) A geometrically similar compressor of three times this size is constructed. Calculate, for this compressor :
 - (A) Speed
 - (B) mass flow rate
 - (C) Pressure ratio
 - (D) The power required

Assume same entry conditions and efficiency for the two compressors.

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It is proposed to compress air (ideal gas) reversibly from an initial state of 100 KPa and 27°C to a final state of 500 KPa and 27°C. Compare the work required for the following processes : 30

- (i) Heating at constant volume followed by cooling at constant pressure
- (ii) Isothermal compression
- (iii) Adiabatic compression followed by cooling at constant volume.

Given,

For air $C_v = 20.93 \text{ J/mol K}$

$C_p = 29.302 \text{ J/mol K}$

