CSM – 55/19

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) What do you mean by thermodynamic system ? How many thermodynamic systems are there ? Explain with neat sketch. What is the difference between control volume and control surface ? Explain with suitable example. 20

(b) A fluid is confined in a cylinder by a spring-loaded, frictionless piston so that the pressure in the fluid is a linear function of the volume ($p = a + bV$). The internal energy of the fluid is given by the given equation : $U = 38 + 3.18pV$, where U is in kJ, p is in kPa and V is in m^3. If the fluid changes from an initial state of 180 kPa, $0.04m^3$ to a final state of 410 kPa, $0.08m^3$, with no work other than that done on the piston, find the direction and magnitude of the work and heat transfer. 20

(c) A four stroke petrol engine delivers 40 kW with a mechanical efficiency of 85 percent. The fuel consumption of the engine is 0.45 kg per kW-hr and the air-fuel ratio is 14 : 1. The heating value of the fuel is 45000 kJ/kg. Find :

(i) The indicated power,

(ii) The friction power

(iii) The brake thermal efficiency

(iv) The fuel consumption per hour,

(v) The air consumption per hour 20

(d) What do you mean by diesel knock ? How it differs from detonation ? What are the methods to control diesel knock ? 20

2. (a) Air flows steadily at the rate of 0.6 kg/s through an air compressor, entering 8 m/s velocity, 120 kPa pressure, and 0.96 m^3/kg volume, and leaving at 6 m/s, 750 kPa, and 0.20 m^3/kg. The internal energy of the air leaving is 100 kJ/kg greater than that of the air entering. Cooling water in the compressor jackets absorbs heat from the air at the rate of 58 kW.

(i) Compute the rate of shaft work input to the air in kW.

(ii) Find the ratio of the inlet pipe diameter to outlet pipe diameter. 30

(b) A test on a single cylinder four stroke oil engine having bore 18 cm and stroke 36 cm yielded the following results ; speed, 285 rev/min ; brake torque, 393 Nm ; indicated m.e.p., 7.2 bar; fuel consumption, 3.5 kg/hr; cooling water flow, 4.5 kg/min ; cooling water temperature rise 36°C ; air-fuel ratio by mass, 25 ; exhaust gas temperature, 415°C ; barometric pressure, 1.013 bar ; room temperature, 21°C. The fuel has a calorific value of 45200kJ/kg and contains 15% by mass of hydrogen. Determine :

(i) The indicated thermal efficiency.

(ii) The volumetric efficiency based on atmospheric conditions.

(iii) Draw up a heat balance in terms of kJ/min explaining clearly the content of such term

Take : R = 0.287 kJ/kg K ; c_v for dry (b)

exhaust gases = 1.005 kJ/kg K and for superheated steam c_p = 2.05 kJ/kg K. 30

3. (a) A mild steel tank of wall thickness 10 mm contains water at 90°C. The thermal conductivity of mild steel is 50 W/m°C and the heat transfer coefficients for the inside and outside the tank are 2800 and 10 W/ m^{2}°C, respectively. If the atmospheric temperature is 10°C, calculate :

   (i) The rate of heat loss per m^2 of the tank surface area.

   (ii) The temperature of the outside surface of the tank. 30

   (b) In a Bell-Coleman cycle, working between pressure of 2 and 8 bar, and temperature at the starting of compression and expansion of 10°C and 40°C, air flow rate is 35 kg/min. If the compression and expansion indices in

this polytropic process are 1.3 and 1.35 respectively, what is the COP and tonnage of the plant ? Determine the heat transfers per kg of air during each process. 30

4. (a) A counter flow heat exchange, through which passes 12.5 kg/s of air to be cooled from 230°C to 160°C, contains 4200 tubes, each having a diameter of 30 mm. The inlet and outlet temperature of cooling water are 25°C and 65°C respectively. If the water side resistance to flow is negligible, calculate the tube length required for this duty. For turbulent flow inside tubes : $Nu = 0.023\ Re^{0.8}\ Pr^{0.4}$. Properties of the air at the average temperature are as follows :

$\rho = 1.009\ kg/m^3$; $c_p = 1.0082\ kJ/kg°C$; $\mu = 2.075 \times 10^{-5}\ kg/ms\ (Ns/m^2)$ and $k = 3.003 \times 10^{-2}\ W/m°C$. 30

(b) An impulsive stage of a steam turbine is supplied with dry and saturated steam at 14.7 bar. The stage has a single row of moving blades running at 3600 rev/min. The mean diameter of the blade disc is 0.9 m. The nozzle angle is 14° and the axial component of the absolute velocity leaving the nozzle is 93.42 m/s. The height of the nozzle at their exit is 100 mm. The nozzle efficiency is 0.9 and the blade velocity co-efficiency is 0.966. The exit angle of the moving blades. is 2° greater than at the inlet. Determine : 30

(i) The blade inlet and outlet angles

(ii) The isentropic heat drop in the stage

(iii) The stage efficiency

(iv) The power developed by the stage.

SECTION – B

5. Answer any **three** of the following :

(a) Assuming the sun (diameter = 1.4×10^{9} m) as a black body having a surface of 30%.

temperature of 5750 K and at a mean distance of 15×10^{10} m from the earth (diameter = 12.8×10^{6} m), estimate the following :

(i) The total energy emitted by the sun.

(ii) The emission received per m^2 just outside the atmosphere of the earth

(iii) The total energy received by the earth if no radiation is blocked by the atmosphere of the earth

(iv) The energy received by a 1.6 m × 1.6 m solar collector whose normal is inclined at 50° to the sun. The energy loss through the atmosphere is 42 percent and diffuse radiation is 22 percent of direct radiation

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(b) In an electrolux absorption type refrigerator heat is supplied to generator by condensing steam at 2 bar which is 85% dry. The temperature is to be maintained in

refrigerator at $-4^{\circ}C$. If the normal outside (ambient) temp. is fairly constant within $30^{\circ}C$; find out the maximum overall coefficient of performance of system. If refrigeration effect desired is 25 tons and actual COP of system is 80% of the maximum, calculate the weight of steam required per hour. Take saturation temperature at 2 bar as $120^{\circ}C$. 20

(c) (i) What is psychometric chart ? Briefly explain its use with neat sketch.

(ii) What are the environmental factors on which human comfort depends ? Write down the various environmental indices for human comfort in air-conditioning. 20

(d) (i) Draw the load curve of power plant and briefly describe its various features.

(ii) A hydro power plant is to be used as peak load plant at an annual load factor

The electrical energy obtained during the year is 750×10^5 kWh. Determine the maximum demand. If the plant capacity factor is 24% find reserve capacity of the plant. 20

6. (a) Air enters a compressor at 1.5 bar, 35°C, which is also the state of the environment. It leaves at 3.0 bar, 140°C and 100 m/s. Neglecting inlet velocity and P. E. effect, determine :

(i) Whether the compression is adiabatic or polytropic

(ii) If not adiabatic, the polytropic index

(iii) The isothermal efficiency

(iv) The minimum work input and irreversibility. Take c_p of air = 1.0035 kJ/kgK. 30

(b) A spark ignition engine uses fuel-air mixture consisting of 1 part fuel and 13.5 parts air by

mass. Calorific value of the fuel is 44000 kJ/kg. The brake thermal efficiency of the engine is 25%. Find its :

(i) Brake output for a fuel consumption of 1 kg/hr

(ii) Brake specific fuel consumption. What will be the brake output brake specific fuel consumption of a diesel engine having air-fuel ratio of 25 : 1 calorific value of fuel 42,000 kJ/kg and brake thermal efficiency is 38%. Also compare the air consumption of two engines per bhp-hr. 30

7. (a) Air at 20°C and at atmospheric pressure flows at a velocity of 4.5 m/s past a flat plate with a sharp leading edge. The entire plate surface is maintained at a temperature of 60°C. Assuming that the transition occurs at a critical Renolds number of 5×10^5, find the

distance from the leading edge at which the flow in the boundary layer changes from laminar to turbulent. At the location, calculate the following :

(i) Thickness of hydrodynamic layer

(ii) Thickness of thermal boundary layer

(iii) Local and average convective heat transfer coefficients

(iv) Heat transfer rate from both sides for, unit width of the plate

(v) Mass entrainment in the boundary layer

(vi) The skin friction coefficient

Assume cubic velocity profile and approximate method. The thermophysical properties of air at mean film temperature $(60 + 20)/2 = 40^{\circ}C$ are : $\rho = 1.128\ kg/m^3$; $\nu = 16.96 \times 10^{-6}\ m^2/s$; $k = 0.02755\ W/m^{\circ}C$; $Pr = 0.699$. 30

(i) Write down the desirable properties of refrigerant and absorbent for absorption system.

(ii) In an Electrolux absorption type refrigerator heat is supplied to generator by considering steam at 2 bars which is 90% dry. The temperature is to be maintained in refrigerator at $-5^{\circ}C$. If the normal outside (ambient) temp. is fairly constant within $35^{\circ}C$; find out the maximum overall coefficient of performance of system. If refrigeration effect desired is 20 tons and actual COP of system is 75% of the maximum, calculate the weight of steam required per hour. Take saturation temperature of steam at 2 bar as $120^{\circ}C$. 30

8. (a) Steam leaves the nozzles of a single-stage impulse turbine at the speed 900 m/s. Even

though the blades are not equiangular, the blade speed is set at the optimum for equiangular blades when the nozzles are at the angle 68°. The velocity coefficient of the nozzles is $C_N = 0.97$, and for the rotor blades it is $C_R = 0.95$. The absolute value of the relative flow angle at the exit of the rotor is 3° greater than the corresponding inlet flow angle. Find :

(i) The total-to-static efficiency.

(ii) Find again the total-to-static efficiency of the turbine, assuming that it operates at the same conditions, but has equiangular blades. If one efficiency is higher than the other, explain the reason ; if they are the same, give an explanation for this as well. 30

(b) A backward curved centrifugal compressor is to compress refrigerant R134a. The

diameter of the impeller is 0.6 m and the blade angle is 60°. The peripheral area is 0.002 m^2 and the flow coefficient (ratio of normal component of velocity to tip speed) is 0.5. If the pressure and temperature of refrigerant at the exit of the impeller are found to be 7.702 bar and 40°C, find the specific work and power input to the compressor. The impeller rotates at 9000 RPM. The tangential component of velocity at the inlet to the impeller may be assumed to be negligible.

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