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HPAS (M)—2014

MECHANICAL ENGINEERING

Paper II

Time : 3 Hours *Maximum Marks :* 150

Note :— (1) Attempt total *Five* questions.

(2) Question No. 8 is compulsory.

(3) Use of Non-programmable calculator, steam tables, Mollier diagram, Psychometric chart and Refrigerant property table is permitted.

(4) Suitably assume missing data, if any.

1. (*a*) A vertical sided 2 m height tank is square whose side is 1 m long. The tank contains oil of specific gravity 0.8 to a depth of 80 cm

P.T.O.

floating on 1.2 m depth of water. Determine :

(*i*) Total pressure one-one side of the tank.

(*ii*) Height of centre of pressure above the base. 15

(*b*) Compare the heat loss from an insulated and an uninsulated copper pipe under the following conditions. The pipe (K = 400 W/mK) has an internal diameter of 10 cm and an external diameter of 12 cm. Standard steam flows inside the pipe at 110°C. The pipe is located in a space of 30°C and the heat transfer coefficient on its outer surface is estimated to be 15 W/m^2K. The insulation available to reduce heat losses is 5 cm thick and its conductivity is 0.20 W/mK. 15

2. (a) The velocity potential function ϕ is given by an expression : 8

$$\phi = \frac{xy^3}{3} - x^2 + \frac{x^3 y}{3} + y^2 .$$

(i) Find velocity component in x and y direction.

(ii) Show that ϕ represents a possible case of flow.

(b) A Pelton wheel is to be designed for shaft power 9560 kW, head 350 m, speed 750 r.p.m., overall efficiency 0.85 and jet diameter not to exceed 1/6 of the wheel diameter. Determine :

(i) Wheel diameter,

(ii) Jet diameter, and

(*iii*) Number of jets required. Take nozzle velocity coefficient $C_v = 0.985$ and speed ratio = 0.45. 10

(*c*) Dry saturated steam at 100 bar expands isothermally and reversibly to a pressure of 10 bar. Calculate the heat supplied and the work done per kilogram of steam during the process. 12

3. (*a*) Estimate the critical pressure and the throat area per unit mass flow rate of a convergent-divergent nozzle expanding steam from 10 bar, dry saturated, down to atmospheric pressure of 1 bar. Assume that the inlet velocity is negligible and that the expansion is isentropic. 8

(*b*) An air-conditioned room is to maintained at 18°C, percentage saturation 40%. The fabric heat gains are 3000 W and there are a maximum of 20 people in the room at any time. Neglecting all other heat gains or losses, calculate the required volume flow rate of air to be supplied to the room and its percentage saturation when the air supply temperature is 10°C.

Data :

Sensible heat gain per person = 100 W

Latent heat gain per person = 30 W

Barometric pressure = 1.01325 bar 15

(c) A single-stage reciprocating compressor takes 1 m^3 of air per minute at 1.013 bar and 15°C and delivers it at 7 bar. Assuming that the law of compression is $pV^{1.35}$ is constant, and that clearance is negligible, calculate the indicated power. 7

4. (a) From a performance test on a well-baffled single-shell, two-tube-pass heat exchanger the following data are available : oil (Cp = 2100 J/kgK) in turbulent flow inside the tubes entered at 340 K at the rate of 1.00 kg/s and left at 310 °K; water flowing on shell side entered at 290 K and left at 300 K. A change in service

conditions requires the cooling of a similar oil from an initial temperature of 370 K but at three-fourths of the flow rate used in the performance test. Estimate the outlet temperature of the oil for the same water flow rate and inlet temperature as before. 15

(*b*) The first stage of a turbine is a two-row velocity compounded impulse wheel. The steam velocity at inlet is 600 m/s, the mean blade velocity is 120 m/s, and the blade velocity coefficient for all blades is 0.9. The nozzle angle is 16° and the exit angles for the first row of moving blades, the fixed blades and the second row of moving blades are 18, 21 and 35° respectively. Calculate :

(*i*) The blade inlet angle for each row.

(*ii*) The driving force for each row of moving blades and the axial thrust on the wheel for a mass flow rate of 1 kg/s.

(*iii*) The diagram power per kilogram per second steam flow, and the diagram efficiency for wheel.

(*iv*) The maximum possible diagram efficiency for the given steam inlet velocity and nozzle angle. 15

5. (a) The vapour pressure in mm of mercury of solid ammonia is given by :

$\ln p = 23.03 - \frac{3754}{T}$ and that of liquid ammonia by :

$$\ln p = 19.49 - \frac{3063}{T}$$

(i) What is the temperature of triple point ? What is the pressure ?

(ii) What are the latent heats of sublimation and vaporization ?

(iii) What is the latent heat of fusion at the triple point ? 12

(b) A two-stroke diesel engine having a stroke to bore ratio of 1.2. The compression ratio is 16 and runs at 1500 r.p.m. During a trial run the following observations were made :

Exhaust pressure	:	1.05 bar
Inlet air temperature	:	36°C
Fuel flow rate	:	2.95 kg/h
Diameter of the cylinder	:	100 mm

The fuel-air ratio was 0.045. Calculate the scavenging efficiency and the scavenging delivery ratio of the engine. 12

(*c*) A battery does work by producing an electric current while transferring heat with a constant temperature atmosphere. Is this a violation of the second law ? 6

6. (a) A petrol engine having a compression ratio of 6 uses a fuel with calorific value of 42 MJ/kg. The air-fuel ratio is 15 : 1. Pressure and temperature at the start of the suction stroke is 1 bar and 57°C respectively. Determine the maximum pressure is the cylinder if the index of compression is 1.3 and the specific heat at constant volume is given by $C_v = 0.678 + 0.00013\ T$, where T is in Kelvin. Compare this value with that obtained when $C_v = 0.717$ kJ/kgK. 12

(b) Air contained in an insulated, rigid volume at 20°C and 200 kPa. A peddle wheel, inserted in the volume, does 720 kJ of work on the air. If the volume is 2 m^3, calculate the entropy increase assuming constant specific heats. 10

(c) The directional emissivity of an oxidized surface at 800 K can be approximated by : 8

$$(\theta) = 0.70 \cos \theta$$

Determine :

(i) The emissivity perpendicular to the surface.

(ii) The hemispherical emissivity and

(iii) The radiant emissive power if the surface is 5 cm × 10 cm.

7. (a) An aircraft flying at an altitude of 8000 m, where the ambient air is at 0.341 bar pressure and 263 K temperature, has a speed of 900 km/h. The pressure ratio of the air compressor

is 5. The cabin pressure is 1.0135 bar and the temperature is 27°C : 12

(i) Determine the power requirement of the aircraft for pressurization (excluding the ram work) additional power required for refrigeration and refrigerating capacity on the basis of 1 kg/s flow of air.

(ii) Determine the same if the following are to be accounted :

Compressor efficiency $\eta_c = 0.82$

Expander/turbine efficiency $\eta_T = 0.77$

Heat exchanger effectiveness $\epsilon = 0.8$

Ram efficiency $\eta_R = 0.84$

(*b*) Air enters the compressor of a gas turbine at 100 kPa and 25°C. For a pressure ratio of 5 and maximum temperature of 850°C, determine the Back Work Ratio (BWR) and the thermal efficiency for this Brayton cyclic using the ideal gas equation. 8

(*c*) The analysis of gas is as follow :

H_2 49.4%; CO 18%, CH_4 20%; C_4H_8 2%; O_2 0.4%, N_2 6.2%; CO_2 4%.

Calculate :

(*i*) The stoichiometric A/F ratio;

(*ii*) The wet and dry analysis of the products of combustion if the actual mixture is 20% weak. 10

8. Write notes on : 6×5=30

(*i*) Knocking

(*ii*) Nuclear power plant

(*iii*) Energy management and audits

(*iv*) Intercooling in gas turbines

(*v*) The Bernoulli equation

(*vi*) Cavitation.