2022

MECHANICAL ENGINEERING

PAPER-II

Time Allowed — 3 Hours *Full Marks — 200*

If the questions attempted are in excess of the prescribed number, only the questions attempted first up to the prescribed number shall be valued and the remaining ones ignored.

*Answers may be given either in **English** or in **Bengali** but all answers must be in one and same language.*

Any data if needed may be assumed, but it must be clearly mentioned.

Answer any five questions

1. (a) At the inlet to a certain nozzle, the enthalpy of the fluid passing is 3000 kJ/kg and the velocity is 60 m/s. At the discharge end, the enthalpy is 2760 kJ/kg. The nozzle is horizontal and there is negligible heat loss from it. Find the velocity at the nozzle exit. If the inlet area is 0.1 m^2 and specific volume at inlet is 0.187 m^3/kg, find the mass flow rate. If the specific volume at the nozzle exit is 0.498 m^3/kg, find the exit area of the nozzle.

   (b) A heat engine is used to drive a heat pump. The heat transfers from the heat engine and from the heat pump are used to heat the water circulating through the radiators of a building. The efficiency of the heat engine is 27% and COP of the heat pump is 4. Evaluate the ratio of the heat transfer to the circulating water to the heat transfer the heat engine.

20+20=40

2. (a) With the help of the T-s and h-s diagrams, describe the working principle of a reheat Rankine cycle. Define the steam rate and heat rate of a Rankine cycle.

   (b) Consider a steam power plant operating on the ideal reheat Rankine cycle. Steam enters the high-pressure turbine at 15 MPa and 600°C and is condensed in the condenser at a pressure of 0.1 MPa. If dryness fraction at the low-pressure turbine exit is not allowed to fall below 0.896, estimate the pressure at which steam should be reheated. Also determine thermal efficiency of the reheat Rankine cycle. Assume that the steam is reheated to the inlet temperature of the high-pressure turbine. Steam table is allowed.

10+30=40

3. (a) With a neat sketch and a T-s diagram describe operation of an ideal Brayton cycle. Show that the efficiency of an ideal Brayton cycle is a function of its pressure ratio.

(b) In an air standard Brayton cycle, the compression ratio 16, and at the beginning of isentropic compression, the temperature is 15°C and the pressure is 0.1 MPa. Heat is added until the temperature at the end of the constant pressure process is 1480°C. Calculate the cut-off ratio, the heat supplied per kg of air, the cycle efficiency and mean effective pressure.

15+25=40

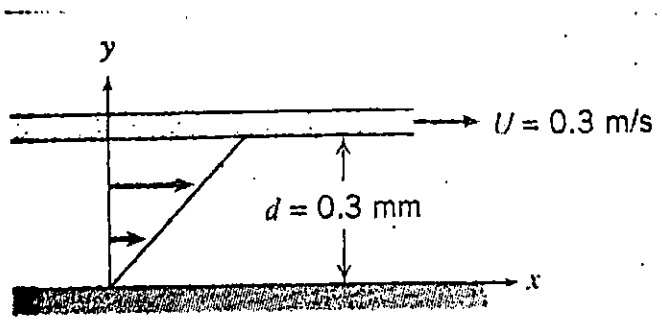
4. (a) Derive the expression of heat transfer through uniform cross-sectional area fin assuming heat loss from the fin-tip is negligible. Define fin efficiency and effectiveness.

(b) The aluminium square fins (0.5 mm× 0.5 mm) and 10 mm length are provided on a surface of a semiconductor electronic device to carry 1 W of energy generated by the electronic device. The temperature of the surface of the device should not exceed 80°C when the surrounding temperature is 40°C. Neglecting the heat loss from the fin tip, estimate the number of fins required to carry out the above duty. It is given that the thermal conductivity of the fin material is 200 W/m °C and the convective heat transfer coefficient is 15 w/m^2 °C.

(c) An oil cooler for a large diesel engine is to cool engine oil from 60°C to 45°C, using seawater at an inlet temperature of 20°C with a temperature rise of 15°C. The design heat load is Q=140 kW and the overall heat transfer coefficient is 80 W/m^2 K. Find the heat transfer surface area for single pass counter flow and parallel flow arrangement.

10+15+15=40

5. (a) An infinite plate is moved over a second plate on a layer of liquid as shown. For small gap width d, we assume a linear velocity distribution in the liquid. The liquid velocity is 0.0065 g/cm.s and its specific gravity is 0.88.



Determine:

(i) The absolute viscosity of the liquid in N.s/m^2.
(ii) The kinematic viscosity of the liquid in m^2/s.
(iii) The shear stress on the upper plate in N/m^2.
(iv) The shear stress on the lower plate in Pa.
(v) The direction of each shear stress calculated in parts (iii) and (iv).

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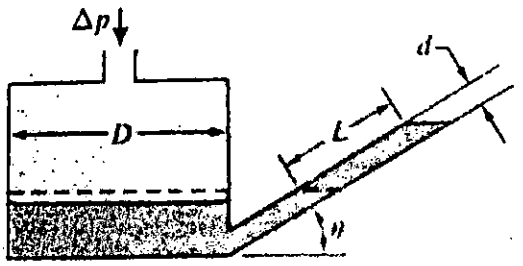
(b) An inclined tube reservoir manometer is constructed as shown. Derive a general expression for the liquid deflection, L in the inclined tube, due to the applied pressure difference, Δp. Also obtain an expression for the manometer sensitivity.



20+20=40

6. (a) A hot air balloon (approximated as a sphere of diameter 15 m) is to lift a basket load of 2670 N. To what temperature must the air be heated in order to achieve liftoff?

(b) Water flows under a sluice gate on a horizontal bed at the inlet to a flume. Upstream from the gate, the water depth is 0.45 m and speed is negligible. At the vena contracta downstream from the gate, the flow streamlines are straight and the depth is 50 mm. Determine the flow speed downstream from the gate and discharge in cubic meter per second per meter of width.

20+20=40

7. (a) The basic design of a centrifugal pump has a dimensionless specific speed of 0.075 rev. The blades are forward facing on the impeller and the outlet angle is 120° to the tangent, with an impeller passage width at outlet being equal to one-tenth of the diameter. The pump is to be used to raise water through a vertical distance of 35 m at a flow rate of 0.04 m^3/s. The suction and delivery pipes are each of 150 mm diameters and have a combined length of 40 m with a friction factor of 0.005. Other losses at pipe entry, exit, bends, etc. are three times the velocity head in the pipes. If the blades occupy 6% of the circumferential area and the hydraulic efficiency (neglecting slip) is 76 %, what must be the diameter of the pump impeller.

(b) A power station supplies the following loads to the customers:

Time in hours	0-6	6-10	10-12	12-16	16-20	20-22	22-24
Load in MW	30	70	90	60	100	80	60

i) Estimate the load factor of the plant.

ii) What is the load factor of a standby equipment of 30 MW capacity if it takes up all loads above 70 MW? What is its use factor?

20+20=40