Time: 3 hrs   Marks: 80

1. *Question No.1 is compulsory.*
2. *Solve ANY THREE questions from the remaining five questions.*
3. *Figure to the right indicates full marks.*
4. *Assume suitable data wherever required, but justify the same.*

Marks

Q. 1   Solve **ANY FOUR** questions from following. (Each question carries **5 marks**)   20

a)   What is thermal diffusivity? How does thermal diffusivity influence transient heat conduction in solids?.

b)   Explain the following non dimensional numbers applied to heat transfer by convection:
(i) Nusselt Number
(ii) Prandtl Number
(iii) Grashoff Number
Explain how the Prandtl number influences the relative thickness of the velocity and thermal boundary layer, also Show how the Grashof number acts as the equivalent of the Reynolds number in natural convection.

c)   A cylindrical wire carrying current is insulated to minimize heat loss. However, it is observed that after adding insulation, the wire's temperature increases. Explain this behavior and derive the condition for the critical radius of insulation.

d)   Explain Biot number and Fourier number applied to transient heat transfer, give significance.

e)   Define ignition lag and discuss how it affects engine knocking in SI and CI engines.

f)   Discuss the advantages and limitations of thermal and catalytic converters in automobile exhaust emission control systems.

Q. 2   a)   During a test on a single-cylinder, four-stroke diesel engine having a cylinder   8
diameter of 22 cm and a stroke length of 45 cm, the following observations were made. The mean effective pressure recorded was 6.5 bar, the torque developed was 420 N·m, and the engine speed was 300 rpm. The fuel consumption during the trial was 4.2 kg per hour, and the calorific value of the fuel used was 42 MJ per kilogram. The cooling water was supplied at a rate of 5 kg per minute, and the air used per kilogram of fuel was 28 kg. The rise in temperature of the cooling water was observed to be 40°C, while the exhaust gases left the engine at a temperature of 410°C when the room temperature was 25°C. The mean specific heat of the exhaust gases was taken as 1.05 kJ/kg·K, and the specific heat of water was 4.18 kJ/kg·K.
From these data, determine the indicated power (I.P.) and brake power (B.P.) of the engine and prepare a complete heat balance sheet for the test on a kJ per hour and percentage basis.

94652   **Page 1 of 3**

Composit insualationg wall consists of three layers. These are held together by 2

b) cm diamerter aluminiurn revet per 0.1 m^2 of surface . the layers consists or 10 cm   12
thick brick with hot surface at 190 °C, 1cm thick wood with cold surface at 20 °C. These two layers are interposed by a third layer of insulating material 25 cm thick.

Assuming one dimensional heat flow, calculate the percentage increased in heat transfer rate due to rivets. The conductivity of material are, k_{brick} = 1 W/mk, $k_{insulation}$ =0.2 W/rnk, k_{wood} = 0.2 W/mk, k_{Al} = 220 W/mk.

Q. 3 a) A 6-cylinder 4-stroke C.I. engine develops 220 kW at 1500 r.pm. with brake   8
specific fuel consumption of 0.273 kg/kWh. Determine the size of the single hole injector nozzle if the injection pressure is 160 bar and the pressure in the combustion chamber is 40 bar. The period of injection is 30° of crank angle. Specific gravity of fuel = 0.85 and orifice discharge coefficient = 0.9.

A 4-cylinder, 4-stroke C.I. engine develops 180 kW at 2000 rpm with a brake specific fuel consumption (b.s.f.c.) of 0.26 kg/kWh.

Determine the size (diameter) of the single-hole injector nozzle if:

Injection pressure = 200 bar

Pressure in the combustion chamber = 60 bar

Period of injection = 25° of crank angle

Specific gravity of fuel = 0.84

Coefficient of discharge (Cd) = 0.88

Find:

1. Fuel flow rate per second
2. Fuel injected per cycle per cylinder
3. Injection duration (in seconds)
4. Orifice area and diameter of nozzle hole

b) A flat plate measuring 0.8 m wide and 2 m long is to be maintained at a uniform   12
surface temperature of 120°C, while air at 25°C flows over it in parallel direction. Determine the air velocity required such that the total rate of heat dissipation from both sides of the plate is 6 kW.

$$\overline{Nu} = \frac{\overline{h}L}{k} = 0.664(Re_L)^{1/2}(Pr)^{1/3} \qquad \ldots\ldots\ldots\ldots \text{ for laminar flow}$$

$$\overline{Nu} = \frac{\overline{h}L}{k} = [0.036\,(Re_L)^{0.8} - 836](Pr)^{1/3} \qquad \ldots\ldots\ldots\ldots \text{ for turbulent flow}$$

Take the following properties of air at 50°C: ρ = 1.0877 kg/m^3, k = 0.02813 W/m°C, c_p = 1007.3 J/kg°C, μ = 2.029 × 10^{-5} kg/ms and Pr = 0.7

Q. 4 a) A rectangular fin, 8 mm thick and 60 mm long, is attached to a wall maintained   8
at a uniform temperature of 150°C. The surrounding air temperature is 30°C. The fin material is brass with a thermal conductivity of 110 W/m·°C, and the convective heat transfer coefficient between the fin surface and air is 95 W/m^2·°C.

Assuming convective heat loss from the tip of the fin is significant, determine:

1. The temperature at the tip of the fin,
2. The total heat dissipated by the fin per metre width of the plate
3. The fin efficiency.

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b) In a counter-flow double-pipe heat exchanger, oil is used to heat water. Oil enters   12
the exchanger at 120°C and leaves at 80°C, flowing at a rate of 25,000 kg/h. The
water enters at 40°C and is heated to about the same temperature as the outlet
temperature of the oil, such that the log mean temperature difference (LMTD)
approaches zero. Assume for $c_{p\ water}$ = 4.2 kJ/kg K, $c_{p\ oil}$ = 2.1 kJ/kg K. The
overall heat transfer coefficient for the exchanger is 350 W/m²·K.
Determine:
1. The heat transfer rate (in kW).
2. The required heat transfer area when the LMTD → 0 (showing how the
   area tends to become extremely large).
3. The effectiveness of the heat exchanger.

Q. 5   a)   The effective temperature of a body having an area of 0.12 m² is 527°C. Calculate   5
the following:
(i) The total rate of energy emission,
(ii) The intensity of normal radiation
       b)   Explain Willan's line method for measurement of frictional power.   5
       c)   Differentiate between the efficiency and effectiveness of an extended surface.   5
       d)   Explain with sketches the temperature profiles for: 5
(i) Boiler,(ii) Condenser, and(iii) Regenerative heat exchanger.

Q. 6   a)   What is the critical heat flux (CHF) or burnout point on a boiling curve? Discuss   5
its physical significance and factors affecting it.
       b)   A four-stroke, six-cylinder gas engine has a bore of 18 cm and a stroke of 32 cm,   5
and runs at 250 rpm, firing every cycle. The air–fuel ratio is 5:1 by volume, and
the volumetric efficiency on the NTP basis is 78%. The temperature of the intake
air is 30°C, and the intake pressure is 0.95 bar.
(a) Determine the volume of gas consumed per minute under NTP conditions.
(b) If the calorific value of the gas is 9 MJ/m³ at NTP and the brake thermal
efficiency of the engine is 28%, calculate the brake power developed by the
engine.
(c) If the mechanical efficiency of the engine is 80%, determine the indicated
power and the indicated thermal efficiency.
       c)   Explain the effects of engine variables (compression ratio, spark timing, mixture   5
strength, and cooling) on knocking tendency. .
       d)   Explain the concept of mass transfer coefficient **and** its relationship with Fick's   5
law.

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