2017

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 the same language.

Answer any five questions

Q:1

(a) What do the areas enclosed by a thermodynamic cycle on *P-v* and *T-s* diagrams represent? What do they signify when the cycle takes place in (i) counter-clockwise direction, (ii) clockwise direction?

(b) Discuss about octane and cetane number in connection with anti-knocking fuel properties.

(c) Explain the significance of specific speed and its importance in selecting hydraulic turbines and pumps

(d) List the dimensionless terms you can identify in Darcy-Weisbach equation for head loss through a circular pipe

e) Explain why Direct-Injection system is preferred in large slow C.I. engines while Indirect-Injection system is preferred in small high speed C.I. engines.

[5x8]

Q.2

a) Plot the following processes on schematic psychrometric chart: (i) sensible heating and (ii) humidification.

[4+4]

b) What happens to the relative humidity and the absolute humidity for the processes mentioned in (a) above?

[6+6]

c) A refrigerator uses refrigerant-134a as the working fluid and operates on an ideal vapor-compression refrigeration cycle between 0.14 and 0.8 MPa. The mass flow rate of the refrigerant is 0.05 kg/s. Work out the following:

i) Draw the schematic block diagram and ii) plot the cycle on T-s diagram, and iii) determine (a) the rate of heat removal from the refrigerated space, (b) the power input to the compressor and (c) the COP of the refrigerator.

You can use Tables 1 & 2 furnished below for the problem.

[4+4+(5+5+2)]

Table 1 Relevant part of thermodynamic property table for saturated refrigerant 134a

Pressure kPa	Sat Temp T_{sat} °C	Specific Volume m^3/Kg		Enthalpy kJ/Kg			Entropy kJ/Kg.K		
		Sat. liq v_f	Sat. vapor v_g	Sat liquid h_f	Evap. h_{fg}	Sat. vapor h_g	Sat. liquid s_f	Evap. s_{fg}	Sat. vapor S_g
140	18.77	0.0007383	0.14014	27.08	212.08	239.16	0.11087	0.83368	0.94456
800	31.31	0.0008458	0.025621	95.47	171.82	267.29	0.035404	0.56431	0.91835

Table 2 Relevant part of thermodynamic property table for superheated refrigerant 134a

P = 0.80 MPa (T_{sat}= 31.31°C)

Temp °C	Specific Volume m^3/Kg	Enthalpy kJ/Kg	Entropy kJ/Kg.K
31.31 (T_{sat})	0.025621	267.29	0.91835
40	0.0270	276.45	0.94800

Q.3 a) An engine working on air standard Otto cycle has a cylinder diameter of 10 cm and stroke length of 15 cm. The characteristic gas constant of air is 287 J/kg.K while its specific heat at constant pressure is taken as 1004.50 J/kg.K. For the engine, work out the following:

i) If the clearance volume be 196.3 c.c. and the heat supplied per kg of air per cycle be 900 kJ/kg, calculate the work output per cycle per kg of air.

ii) If the engine works on 4-stroke cycle and runs at a speed of 600 rpm calculate the power output of the engine in kW. Take the pressure and temperature at the start of compression as 95 kPa and 50° C.

[15+10]

b)

i) Draw a block diagram of a gas turbine engine with regeneration and

ii) the T-s diagram of a corresponding air standard modified Brayton cycle showing the region of regeneration on it.

[8+7]

Q.4

a)

i) Deduce the expression for critical thickness of insulation for a circular pipe and

ii) show the variation of heat transfer with outer radius of the insulated pipe. Consider only convection heat transfer from the outer surface of the insulation.

[10+5]

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b) Derive the governing differential equation for temperature distribution in a rectangular fin when the heat transfer from/to the fin external surfaces is through convection only. Write the boundary condition at the fin tip for i) an infinitely long fin and ii) an insulated- tip fin

[20 +5]

Q5 (a) Represent graphically the variation of shear stress with rate of deformation for a Newtonian fluid and Non-Newtonian fluids.

[5]

(b) The space between two large flat and parallel walls 25mm apart is filled with a liquid of absolute viscosity 0.7 Pa-s. Within this space, a thin flat plate 250mm×250mm is towed at a velocity 150mm/s at a distance of 6mm from one wall, the plate and its movement being parallel to the walls. Considering a linear velocity distribution on either side of the plate, determine the force exerted by the fluid on the plate.

[10]

(c) A rectangular plane, 1.2m×1.8m is submerged in water and makes an angle of 30^0 with the horizontal, the 1.2m sides being horizontal. Calculate i) the magnitude of the force on one face and ii) the position of the center of pressure when the top edge of the plane 500mm below the water surface.

[12+13]

Q.6 (a) A power plant has the following annual factors: load factor = 0.75, capacity factor = 0.60, plant use factor = 0.65. Maximum demand is 60 MW. Estimate (a) the annual energy production, (b) the reserve capacity over and above the peak load and (c) the hours during which the plant is not in service.

[8+6+6]

(b) List the advantages of modern high pressure boilers.

[10]

(c) Sketch a block diagram starting from F.D. fan inlet up to the exit of chimney following the air/flue gas path and show a typical pressure distribution of air/flue gas as it passes through the different components in its flow path in the boiler.

[5+5]

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Q.7 a) In a condenser, water enters at 30^0C and flows at the rate of 1500 kg/hr. The condensing; steam is at a temperature of 120^0C and cooling water leaves the condenser at 80^0C. Specific heat of water is 4.187 kJ/K. If the overall heat transfer coefficient be 2000 W/m^2K, determine the heat transfer area necessary for the purpose.

[20]

b) A spherical (diameter 150 mm) solid black body after being heated in a furnace is taken out with a uniform body temperature of 1000^0C. Assuming that the body only emits but does not receive any radiation heat from outside nor there is any convection heat transfer and the body always has a uniform temperature throughout its bulk at any instant of time, determine the temperature of the body after 1 minute. Take Stefan-Boltzman constant as 5.67×10^{-8} W/m^2.K^4. Take the density of the ball material as 7800 kg/m^3 and specific heat as 500 J/kg.K.

[20]

Q. 8 a) The density of a liquid under static condition is a function of elevation z as given by $\rho(z) = \rho_0 - 2z$, where bottom plane of the container is taken as the reference zero for z. Obtain an expression for pressure distribution of the liquid as a function of z.

[15]

b) The pressure of an automobile tire is measured to be 190 KPa (gauge) before a trip and 215 kPa (gauge) after the trip. The local atmospheric pressure is 95 kPa. If the temperature of air in the tire before the trip is 25^0C m calculate the air temperature after the trip taking the volume of the tire to remain unchanged.

[10]

c) Oil of kinematic viscosity 5×10^{-5} m^2/s is used in a flow situation where the prototype is influenced both by viscous and gravity forces. For a model scale ratio of 1:5, what should be the viscosity of the liquid to be used with the model so as to achieve dynamic similarity with regard to these forces?

[15]