MECHANICAL ENGINEERING

PAPER - I

Time Allowed: 3 hours *Maximum Marks: 200*

Candidates should attempt any FIVE questions. Assume suitable data, if necessary and indicate them clearly. Use of Steam Tables, Psychrometric Chart and Refrigeration Tables is permitted.

For air R = 0.287 kJ/kg-K, C_p = 1.005 kJ/kg-K

γ = 1.4, M = 28.966 kg/kg-mole

1. (a) Derive the expression for $(\Delta h)_T$ for a substance that obeys the equation of state given by:

$$p = \frac{RT}{\upsilon} - \frac{a}{\upsilon^2}$$

(10)

(b) 4 kg of water at 40°C are mixed with 6 kg of water at 100°C in a steady flow process.

Calculate

(i) the temperature of resulting mixture,

(ii) the change in entropy, and

(iii) the unavailable energy with respect to the energy receiving water at 40°C.

(10)

(c) An inventor claims to have developed a device which requires no energy transfer by work or heat transfer, yet able to produce hot and cold stream of air from a single stream of air at an intermediate temperature of 21°C and a pressure of 5·2 bar, separate streams of air exit at a temperature of 1 bar. Sixty percent of mass entering the device exists at the lower temperature. Evaluate the inventor's claim, assuming ideal gas as working fluid and neglecting changes in kinetic and potential energy.

(20)

2. (a) List the objectives of supercharging. Sketch the various configurations of supercharger. Why supercharging is not preferred with single cylinder engine?

(10)

(b) Sketch nearly a sample nuclear reactor and label it. Explain briefly the function of each element of the nuclear reactor.

(c) A sharp edged circular orifice of diameter 3·8 cm and coefficient of discharge as 0·6 is used to measure air consumption of a four stroke petrol engine. Pressure drop through the orifice is 145mm of water and barometer reads 75·5 cm of Hg. The compression ratio of the engine is 6 and the piston displacement volume is 2000 cm^3.

The temperature of air is taken to be 26°C. At 2600 rpm, the engine brake power recorded is 29·5 kW. The fuel consumption is 0·14 kg/mm and the calorific value of fuel used is 43960 kJ/kg.

Calculate the following:

(15)

(i) Volumetric efficiency.

(ii) Air-fuel ratio.

(iii) Brake means effective pressure.

(iv) Brake thermal efficiency.

(v) Relative efficiency.

3. (a) What do you mean by critical thickness of insulation for pipes ? Derive an expression for optimum critical radius and show the variation of heat transfer with radius. Give some practical examples of using critical thickness of insulation.

(10)

(b) A process industry employs a counter-flow heat exchanger to cool 0·8 kg/s of oil (C_p = 2.5 kJ/kg K) from 120°C to 40°C by the use of water entering at 20°C. The overall heat transfer coefficient is estimated to be 1600 W/m^{2}K. It is assumed that the exit temperature of water will not exceed 80°C. Using NTU method and taking NTU = 4 in this case, calculate the following:

(i) Mass flow rate of water.

(ii) Surface area required.

(iii) Effectiveness of heat exchanger.

(10)

(c) An industrial furnace employs a hollow brick lining. The inside and outside surfaces of hollow brick lining are maintained at 900 K and 430 K by placing the radiation shields in between the hollow space. The heat loss to the furnace surroundings at 300 K is both by radiation and natural convection. By sketching the arrangement, calculate the number of radiation shields needed. The emmissivity of the wall and the shields may be taken as 085. The convective heat transfer coefficient is governed by the expression,

$h = 1{\cdot}5\ (\Delta T)^{0.33}$ W/m^{2}K.

(20)

4. (a) What is the purpose of undercooling in vapour compression refrigeration system ? Differentiate between dry and wet compression. What are the advantages of one over the other?

(5)

(b) Draw a neat sketch of air-conditioning system required in winters. Explain the working of different components in the circuit.

(15)

(c) The compressed air from the main compressor of an aircraft cooling system is bled off at 4·5 bar and 200°C. It is then passed through the heat exchanger in which the ram air is forced through for cooling purposes by the fan driven by the cooling turbine. The condition of the inlet to the cooling turbine is 4 bar and 30°C. The air expands in the cooling turbine upto 07 bar. The isentropic efficiency of the turbine is 80% and the flow rate in the turbine is 30 kg/mm. By drawing the system and showing the process on T-s diagram, find

(i) the actual exit temperature from the cooling turbine.

(ii) the power delivered to the ram air blow fan.

(iii) the tons of refrigeration, if the cold air is tempered by mixing with by-passed warm air and delivered to the cabin cockpit area where it warms upto 25°C before exhausting out to waste.

(20)

5. (a) The quantity of water flowing through a channel is measured notch weir. The water head over the notch is thrice the breadth of the rectangular notch. If the rectangular notch is replaced by a V-notch, calculate the angle of V-notch, other conditions remaining the same. The coefficient of discharge for V-notch is 0·6 and for a rectangular notch is 0·64.

(5)

(b) Calculate the mass flow rate of oxygen through a 100 mm diameter horizontal pipe if the inlet pressure is 1·06 m of mercury. The diameter at the throat is 30 mm. The ratio of pressure between the venturimeter and the inlet is 0·9. Take $\gamma = 1{\cdot}4$ and density of oxygen gas is 1·429 kg/m^3.

(15)

(c) Two inward flow reaction turbines have the same diameter viz 0.7 m and the same efficiency. Both the runner work under the same head and they have the same velocity of flow, viz 5·8 m/s. One of the runner, A revolves at 500 rpm and the inlet blade angle is 65°. If the other runner, B has an inlet blade angle of 110°, at what speed should it run?

(20)

6. (a) Explain the working principle of Hot-wire Anemometry to measure the velocity of fluid with the help of a sketch.

(10)

(b) State the Buckingham π theorem and hence obtain an expression for the thrust developed by a propeller which depends upon the angular velocity ω, approach velocity V dynamic viscosity μ, density ρ, propeller diameter D and the compressibility of the medium measured by the local velocity of sound C.

(15)

(c) A pelton turbine is to work at the foot of dam whose reservoir level is 220 m. The head at the full opening at the turbine nozzle is 200 m and the coefficient of velocity is 0·98. The turbine is to operate at 200 rpm and develop a power of 3·7 MW. Assuming the blade to jet speed ratio as 0·46, estimate the wheel diameter. If the blade outlet angle is 16°, determine the blade and hydraulic efficiencies. Neglect frictional losses.

(15)

7. (a) What is the purpose of speed governing in steam turbine?

Discuss hydromechanical governing loop.

(10)

(b) Derive the expressions for maximum blade efficiency and maximum power output from a single stage impulse turbine. Give physical explanation.

(10)

(c) A steam nozzle receives steam at 40 bar and 400°C at an initial velocity of 40 m/s. The final pressure of steam is 10 bar. The mass flow rate of steam is 2 kg/s. The nozzle efficiency is 90%. The cross-section of the nozzle is circular. The angle of divergence is 6°. Calculate the throat and exit diameters and the length of divergent portion. Show the representation of process on h-s diagram and sketch the nozzle and label the dimensions calculated.

(20)

8. (a) Why are downcomers fewer in number and bigger in diameter, while risers are more in number and smaller in diameter in a steam generator ?

(5)

(b) A steam turbine is governed by throttling. The full load output of a steam turbine, measured at the coupling is 5 MW and the losses due to bearing friction, the governor and oil pump drive, etc., is 200 kW. The steam is supplied at a pressure of 20 bar and 300°C. The exhaust pressure of steam is 0.07 bar. The internal efficiency ratio at full load is 0.75. Calculate the coupling power of turbine when the steam flow through the turbine is 20% of that at full load. Assume that the external losses are the same as that of full load, exhaust pressure is the same and the internal efficiency ratio is reduced to 70% at this load.

(15)

(c) An open cycle gas turbine employs a regenerative arrangement. The air enters the compressor at 1 bar and 288 K and is compressed to 10 bar with a compression efficiency of 85%. The air is heated in the regenerator and the combustion chamber till its temperature is raised to 1700 K and during the process pressure falls by 0.2 bar. The air is then expanded in the turbine and passes to regenerator which has 75% effectiveness and causes a pressure drop pf 0·2 bar. The isentropic efficiency of turbine is 86%. By sketching the gas turbine system and showing the process on T-s diagram, calculate the thermal efficiency and power output if mass flow rate of air is 100 kg/s. Take mechanical and alternator efficiency as 98% each, c_{pg} = 1·15 kJ/kgK and c_{pa} = 1·005 kJ/kgK.

(20)

MECHANICAL ENGINEERING

PAPER - II

Time Allowed: 3 hours *Maximum Marks: 200*

Candidates should attempt Question 1 in Section 'A' which is compulsory, TWO questions from Section 'B' and TWO questions from Section 'C'.

Question 1 is of short answer type, limiting answer of each part to 30 words. Assume suitable data, if necessary and indicate the same clearly.

SECTION A

1. (a) What do you mean by alloy steel ? Write effects of following alloying elements on steel

   (i) Nickel

   (ii) Chromium

   (b) Illustrate the graphical comparison of following theories of failures for two-dimensional stress system

   (i) Maximum normal stress theory

   (ii) Maximum shear stress theory

   (iii) Distortion energy theory

   (c) What do you understand by backlash in gears ? Along which circle is it measured? How can we change backlash during mounting of gears ?

   (d) Why is gear finishing done ? Explain 'gear shaving' and 'gear furnishing' finishing operations.

   (e) Explain the pressure angle of cam. Why is high value of pressure angle not preferred?

   (f) What do you understand by 'Selective Assembly' process? How is the range of clearance reduced?

   (g) Explain good 'gating design' in molding. What are its advantages ?

   (h) The torque developed by an engine is given by the equation given below :

   $$T = 14250 + 2200 \sin 2\theta - 1800 \cos 2\theta$$

   where 'T' is the torque in N-m and θ is the crank angle displacement from inner dead centre position. Determine the mean torque.

   (i) What do you mean by 'autogeneous' and 'homogeneous' welding processes?

   Metallurgically name the three distinct zones in a welded part. Enumerate the most important factors governing the fusion welding process.

   (j) Explain 'batch model' and 'mixed model' assembly lines. Enumerate the advantages of 'mixed model' assembly line over 'batch model' assembly line.

   (k) Define 'value'. Differentiate between 'value engineering' and 'value-analysis'. State various phases of value-analysis job plan.

   (l) Illustrate the following probability distributions schematically and specify their applications:

(i) Normal

(ii) Weibull

(iii) Exponential

(m) What do you understand by degree of freedom of planer mechanism ? State the Gruber's Equation to find the d.o.f. of a mechanism.

(n) (i) Explain Lower pairs and Higher pairs.

(ii) What will be the number of inversions in a kinematic chain having 'n' links ?

(iii) State whether the helical gears which are in contact are a 'higher pair' or 'lower pair'.

(o) What is 3 – 2 – 1 principle of location with respect to fixture design? Explain.

(p) A hollow cylinder C.I. column, 3 m long has its internal and external diameters as 80 mm and 100 mm respectively. Calculate the safe load using Rankine Formula, is

(i) both ends are hinged and

(ii) both ends are fixed. Take crushing strength of material as 600 N/mm^2, Rankine constant 1/1600 and factor of safety 3.

(q) How do the slacks in PERT and floats in CPM decide on selection of critical path ?

(r) Draw sketch showing various angles of single point cutting tool for turning aluminium alloys.

(s) What is meant by 'interpolation in CNC programming' ? What for are 'G' and 'M' codes used in NC part programming?

(t) Draw a flow chart to compute crippling load for column with different end conditions.

Euler's equation for crippling load is $P_{cr} = \frac{\pi^2 EI}{l^2}$

$l = L$ for both ends hinged

$l = 2L$ for one fixed and the other free

$l = \frac{L}{\sqrt{2}}$ for one end fixed and one end hinged

$l = L/2$ for both ends fixed

SECTION B

2. (a) A simply supported beam of length 10 m carries a uniformly varying load whose intensity varies from a maximum value of 5 kN/m at both ends to zero at the centre of the beam. It is desired to replace the beam with another simply supported beam which will be subjected to the same maximum 'Betiding Moment' and 'Shear Force' as in the case of the previous one. Determine the length and rate of loading for the second beam, if it is subjected to a uniformly distributed load over its whole length. Draw the variations of 'SF' and 'BM' in both the cases.

(25)

(b) A long strut AS of length l is of uniform section throughout. A thrust P is applied at the ends eccentrically on the same side of the centre line with eccentricity at the end B twice than that at the end A. Show that the maximum bending moment occurs at a distance x from the end A, where

$$\tan kx = \frac{2 - \cos kl}{\sin kl} \text{ and } k = \sqrt{\frac{P}{EI}}$$

3. (a) A full journal bearing operating under a steady load has the following specifications:

(1) Journal diameter : 60 mm

(2) Bearing length : 60 mm

(3) Radial load on bearing : 2·8 kN

(4) Journal speed : 1020 rpm

(5) Radial clearance : 005 mm

(6) Viscosity of oil : 80×10^{-9} N-s/mm^2

(7) Density of oil : 860 kg/m^3

(8) Specific heat of oil : 1·76 kJ/kg-°C

Using Raymonds & Boyd table given at the end of the problem, determine

(i) Summerfield Number

(ii) Power loss in friction

(iii) Temperature rise if heat generated is entirely carried by oil

(iv) Minimum film thickness, and its location

(20)

Table – Giving Raymonds & Boyd data for journal bearing for L/D = 1.

Attitude ε	h_0/c	S	ϕ	$\frac{r}{c}f$	$\frac{Q}{rcn_s l}$	$\frac{Q_s}{Q}$	$\frac{P}{P_{max}}$
0	1·0	00	85	∞	π	0	–
0·1	0·9	1·33	79·5	26·4	3·37	0·150	0·540
0·2	0·8	0·630	74·02	12·8	3·59	0·280	0·529
0·4	0·6	0·264	63·10	5·79	3·99	0·497	0·484
0·6	0·4	0·121	50·58	3·22	4·33	0·680	0·415

(b) A car has a three cylinder engine which produces maximum torque of 200 N-m at 2000 rpm. The power is transmitted by a single plate friction clutch of 230 mm outside diameter. Design dimensions of friction surfaces. Further when the car is engaged at a speed of 60 1cm/hi, calculate the clutch slip period (time) during engagement.

Additional data as under:

(i) Engine speed at beginning of clutch engagement : 2000 rpm

(ii) Engine torque at engagement : 100 N-m

(iii) Mass of car (loaded) : 1500 kg

(iv) Wheel diameter: 710 mm

(v) Coefficient of friction : 0·3

(vi) Permissible pressure for friction material : 0·25 N/mm^2

(vii) Mass moment of inertia of engine rotating parts, flywheel and driving side of clutch 1·5kg-m^2

(viii) Gear reduction at differential : 4·12

(ix) Torque available at the rear wheels : 105 N-m

Uniform wear theory may be used for the clutch plate design.

(20)

4. (a) Define Body Centrode' and 'Space Centrode' for a link in mechanism. Explain how you will find these.

(10)

(b) The crank length of a petrol engine is 50 mm and the connecting rod is 175 mm long and the crank rotates at a uniform speed of 400 rpm. Calculate the velocity and acceleration of the piston at different positions of the piston along its stroke and plot the two curves.

Also find the crank position at which the piston's acceleration becomes zero.

(30)

SECTION C

5. (a) Enumerate the steps involved in 'Powder Metallurgy' process. Discuss these steps. Name the materials used in 'Powder Metallurgy'. What are the limitations of Powder Metallurgy ?

(10)

(b) What do you understand by forging process ?

Name the typical forging processes. Derive the expression for the maximum force required for forging a flat strip. State the assumptions made. The initial thickness of the work- piece is h and the width is $2l$.

(20)

(c) A strip of lead with initial dimensions 24 mm x 24 mm x 150 mm is forged between two flat dies to a final size of 6mm x 96mm x 150 mm. If the coefficient of friction is 0·25, determine the maximum forging force. The average yield stress of lead in tension is 7 N/mm^2.

(10)

6. (a) Mild steel is being machined at a cutting speed of 200 m/min with a tool rake angle of 10°. The widths of cut and uncut thickness are 2 mm and 0·2 mm respectively. If the average value of coefficient of friction between the tool and the chip is 0·5 and the shear stress of the work material is 400 N/mm^2, determine (i) shear angle and (ii) cutting and thrust components of the machining force.

(10)

(b) Explain the grinding process for the following operations : (i) Roll grinding (ii) Thread grinding, and explain speed, feed and depth of cut as applicable to grinding works.

(10)

(c) Define NC, CNC and DNC. Also explain their developments, and improvements in their applications.

(10)

(d) Prepare a part program for machining a rectangular contour of 200 mm x 100 mm size from a suitable MS blank of 5 mm thickness. Also, a reamed hole of 16 mm has to be made centrally in the rectangular contour. Take speeds and feeds arbitrarily.

(10)

7. (a) A company has factories A, B and C which supply warehouses D, E, F and G. Monthly factory capacities are 180, 170 and 200 units respectively. Monthly warehouses requirements are 90, 100, 120 and 180 units respectively. Unit shipping cost in Rupees are given in the table below, Determine the initial feasible solution using Vogel's Approximation and find the optimum distribution for this company.

(20)

		D	E	F	G	Supplies
	A	44	50	40	39	180
Factories	B	42	51	54	53	170
	C	41	40	42	45	200
Requirements		90	100	120	180	

(b) Draw the PERT network for the activities whose three time estimates are given in the table.

Activity	Predecessor activity	Optimistic time	Pessimistic time	Most likely time
A	-	1	5	3
B	-	2	4	3
C	-	3	5	4
D	A	2	10	9
E	C	4	6	5
F	B, D, E	5	13	6
G	A	2	6	4
H	G, F	0	6	3

From the three time estimates obtain the expected times of all the activities and slacks of all the events. Also find the critical path.

(20)