

MECHANICAL ENGINEERING

PAPER - I

Time Allowed: Three Hours

Maximum Marks: 200

Candidates should attempt any FIVE questions.

Assume suitable data if necessary, and indicate them clearly.

For air $R = 0.287 \text{ kJ/kg K}$;

$c_p = 1.005 \text{ kJ/kg K}$; $\gamma = 1.4$

Assume 1 bar 1 kg f/cm², if necessary.

1. (a) Using the Maxwell relation derive the following Tds equation $Tds = c_p dT - T \left(\frac{\delta v}{\delta t} \right)_p dp$ (10)
- (b) A compressed air bottle of volume 0.15 m^3 contains air at 40 bar and 27°C . It is used to drive a turbine which exhausts to atmosphere at 1 bar. If the pressure in the bottle is allowed to fall to 2 bar, determine the amount of work that could be delivered by the turbine. (15)
- (c) A rigid tank contains air at 1.5 bar and 60°C . The pressure of air is raised at 2.5 bar by transfer of heat from a constant temperature reservoir at 400°C . The temperature of surroundings is 27°C . Determine per kg of air, the loss of available energy due to heat transfer. (15)
2. (a) Discuss the formation of exhaust emissions in petrol engines. How do these emissions vary with air-fuel ratio?
Describe with a sketch how a three-way catalytic converter controls pollution in petrol cars. (15)
- (b) A hydrocarbon fuel when burned with air gave the following Orsat analysis:
 CO_2 11.94%, O_2 2.26%, CO 0.41%, N_2 85.39%
Determine (i) the air-fuel ratio on mass basis, (ii) the percent of carbon and hydrogen in the fuel on a mass basis, and (iii) percent of theoretical air supplied.
Assume air contains 21% oxygen by volume. (15)
- (c) Draw a schematic flow diagram of a modern steam generator. Discuss the installation of convection and radiation superheaters and their exit temperature response with varying steam flow. (10)
3. In a counter flow double pipe heat exchanger water flows through a copper tube (19 mm O.D. and 16mm ID.), at a flow rate of 1.48 m/s. The oil flows through the annulus formed by inner copper tube and outer steel tube (30 mm O.D. and 26 mm I.D.). The steel tube is insulated from outside. The

oil enters at 0.4 kg/s and is cooled from 65° C to 50° C whereas water enters at 32° C. Neglecting the resistance of the copper tube, calculate the length of the tube required.

(25)

Data given : $Nu = 0.023 (Re)^{0.8} (Pr)^{0.3}$

Fouling factor, water side 0.0005 m²K/W

Fouling factor, oil side 0.0008 m²K/W

Water and oil properties

Property	Oil	Water
P (kg/m ³)	850	995
c _p (kJ/kg K)	1.89	4.187
K (W/mK)	0.138	0.615
v (m ² /s)	7.44 x 10 ⁻⁶	4.18 x 10 ⁻⁷

(b) The following data refers to design of an air conditioning system of a theatre:

Total seating capacity 600 persons

Sensible heat per person 210 kJ/hr

Latent heat per person 130 kJ/hr

Solar heat gain through glass, doors and walls 2,50,000 kJ/hr

Outside design condition 40° C DBT, 27° C WBT

Inside design condition 24° C DBT, 50% RH

Apparatus dew point temperature of cooling coil 4° C

50% of return air is recirculated and it is mixed with fresh air before entering the cooling coil.

Calculate

(i) the bypass factor of the cooling coil.

(ii) the mass flow rate of supply air to the theatre, and.

(iii) the refrigeration capacity of the coil in tons of refrigeration.

(15)

4. (a) A 20 ton vapour compression refrigeration system using Freon 12 operates between evaporator pressure of 1.004 bar and condenser pressure of 13.663 bar. The system uses a sub-cooling superheating heat exchanger with 10° of superheat added. Determine (i) the mass flow rate, (ii) the COP, (iii) the degree of sub-cooling and (iv) the power required. The refrigerant leaving the condenser is dry saturated liquid and leaving the evaporator is dry saturated vapour. The compression in compressor is isentropic.

(20)

Properties for R-12:

Pressure bar	Temperature °C	Enthalpy kJ/kg		Entropy kJ/kg K		Specific heat, kJ/kg K	
		liquid	vapour	liquid	vapour	liquid	vapour
1.004	-30	8.854	174.076	0.0371	0.7165		0.579

13.663	55	90.201	207.766	0.3194	0.6777	1.074	
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- (b) Derive the following expressions for heat transfer from an extended surface assuming that the loss of heat from the end of the extended surface is negligible. $Q = mKA (t_1 - t_f) \tanh mL$ where the notations have the usual meaning t_1 is the temperature at the root of the extended surface and t_f is the temperature of the surrounding fluid.

What would be the value of fin efficiency to the above case?

(15)

- (c) The filament of a 75 W light bulb maybe considered a black body radiating into a black enclosure at 70° C. The filament diameter is 0.10 mm and the length is 5 cm. Considering only radiation, determine the filament temperature.

(5)

5. (a) A simple impulse turbine has mean blade speed of 200 m/s. The nozzles are inclined at 20° to the plane of rotation of the blades. The steam velocity from nozzles is 600 m/s. The turbine uses 3500 kg/hr of steam. The absolute velocity at exit is along the axis of the turbine. Determine (i) the inlet and exit angles of the blades, (ii) the power output of the turbine, (iii) the diagram efficiency, (iv) the end thrust (per kg steam per second) and its direction.

(20)

- (b) Draw schematic diagrams of Pressurized Water Reactor (PWR) and Boiling-Water Reactor (BWR) and discuss their relative merits.

(10)

- (c) Explain the concept of polytropic efficiency η_{pc} as applied to a multistage rotary compressor. Derive the relationship between isentropic efficiency and η_{pc} polytropic efficiency η_{pc} .

$$\eta_{pc} = \frac{r^{(\gamma-1)\gamma} - 1}{r^{(\gamma-1)\gamma\eta_{pc}} - 1}$$

where r is the pressure ratio of the compressor.

(10)

6. (a) A turbojet unit is flying at a speed of 268 m/s at an altitude where the ambient conditions are 0.20 bar and 220 K. The air enters an ideal diffuser and leaves the combustor at 1350 K and 1 bar. The fuel supplied has a heating value of 43,000 kJ/kg. Assume all compression and expansion processes to be isentropic. Determine

(i) the air-fuel ratio (ii) the specific thrust and (iii) the propulsive efficiency.

Take c_p and γ for the compression process 1.005 kJ/kg K and 1.4 and for combustion and expansion processes 1.102 kJ/kg K and 1.33 respectively.

(25)

- (b) A double-acting single cylinder reciprocating air compressor has a piston displacement of 0.015 m³ per revolution, operates at 500 r.p.m. and has a 5% clearance. The air is received at 1 bar and delivered at 6 bar. The compression and expansion are polytropic with $n = 1.3$. Determine

(i) the volumetric efficiency (ii) the power required, and (iii) the heat transferred and its direction, during compression if inlet temperature of air is 20° C.

(15)

7. The efficiency η of a fan depends on the kinematic viscosity ν of the fluid, the angular velocity ω , diameter D of the rotor and the discharge Q . Express η in terms of dimensionless parameter using Buckingham's π theorem.

(15)

$$\eta = \phi \left[\frac{\omega D^2}{\nu}, \frac{Q}{\omega D^3} \right]$$

- (b) In an aircraft flying at an altitude where the pressure was 35 kPa and temperature -38°C , stagnation pressure measured was 65.4 kPa. Calculate the speed of the aircraft.
- (c) Discuss the air-fuel ratio requirements of a petrol engine automobile for starting and warm up, idling and low load, normal power range, maximum power range and acceleration. State how these requirements are achieved.
8. (a) Explain displacement and momentum boundary layer thickness. Assume that the shear stress varies linearly in a laminar boundary layer such that $\tau = \tau_0 \left[1 - \frac{y}{\delta} \right]$. Calculate the displacement and momentum thickness in terms of δ .
- (b) A pipeline, with diameter 0.8 m and length 3000 m connects two open reservoirs of water which have their water surfaces at elevations of 100 m and 70 m above a datum. In order to increase the rate of flow between the reservoirs by 20% it is decided to lay an additional 0.8 m diameter pipeline from the upper reservoir. The second pipeline is to be parallel to the original pipeline and is to be connected to the latter at some suitable point. Determine the point of connection, assuming that the friction factor λ is 0.04 for each pipeline. Neglect minor losses.
- (c) A centrifugal pump rotating at 1500 r.p.m. delivers $0.2 \text{ m}^3/\text{s}$ at a head of 15 m. Calculate the specific speed of the pump and the power input. Assume overall efficiency of the pump as 0.68.
- If this pump were to operate at 900 r.p.m. what would be the head, discharge and power required for homologous conditions?
- Assume overall efficiency unchanged at new r.p.m.

(10)

MECHANICAL ENGINEERING

PAPER - II

Candidates should attempt question 1 in Section A which is compulsory, TWO question from Section B and Two questions from Section C. Question 1 is of short answer type, limiting answer of each part to 30 words.

SECTION A

1. The hexagonal bolt proportions for pitch, head, thickness, nut thickness, head and nut diameters, etc. are given in terms of nominal diameter – why ?
 - (b) What are the common profiles used for splines in machine elements?
 - (c) What is self locking taper and what is self releasing taper? Give an example each where they are used.
 - (d) What are extreme pressure lubricants ? What are the main additives and how do they act?
 - (e) When using strain-gauge system for stress/force/displacement measurements how are in-built magnification and temperature compensation achieved ?
 - (f) Specific strength of materials is very high when they are in fibre size but lower when they are in bar form — why?
 - (g) How are porous bearings made and where are they used?
 - (h) What are the ingredients of stainless steel and what are their approximate percentages?
 - (i) For winches and cranes wire ropes are preferred to wires – why ?
 - (j) In general terms what is pressure angle ? How is it defined for a cam?
 - (k) The best shape of a runner in sand casting is an inverted frustum of a cone why ?
 - (l) Multiple coated, disposable carbide tips have more-or-less replaced brazed carbide tipped tools in CNC applications — why?
 - (m) State standard point angle and helix angle of a twist drill.
 - (n) State two products each produced by forward extrusion and reverse impact extrusion.
 - (o) What are the best geometrical shapes suggested for sheet metal drawing and spinning ?
 - (p) Expand MRP I and MRP II indicating the differences and similarly.
 - (q) Indicate the similarity and differences between EOQ and EBO in manufacturing.
 - (r) State the similarities and differences between a fixture and a jig.
 - (s) State, sequentially the elements of a canned CNC drilling cycle.
 - (t) What is FORTRAN and for what types of engineering problems is it best suited?

(40)

SECTION B

2. (a) A thin cylinder with closed ends has an internal diameter of 50 mm and a wall thickness of 2.5 mm. It is subjected to an axial pull of 10 kN and a torque of 500 Nm while under an internal pressure of 6 MN/m².
- Determine the principal stresses in the tube and the maximum shear stress.
 - Represent the stress configuration on a square element taken in the load direction with direction and magnitude indicated (schematic).
 - Sketch the Mohr's stress circle. (20)
- (b) A tube 40 mm outside diameter, 5 mm thick and 1.5 m long is simply supported at 125 mm from each end and carries a concentrated load of 1 kN at each extreme end
- Neglecting the weight of the tube, sketch the shearing force and bending moment diagrams, and
 - Calculate the radius of curvature and the deflection of mid-span. Take the modulus of elasticity of the material as 208 GN/m².
 - Give an example where maximum deflection and maximum stress do not occur at the same point.
 - Give an example where they occur at the same point. (20)
3. (a) Two 20° pressure angle involute gears in mesh have a module of 10 mm. The addendum is one module. The larger gear has 50 teeth and the pinion 13 teeth.
- Does interference occur ?
 - If it occurs, to what value should the pressure angle be changed to eliminate interference ?
 - Represent schematically the meshing of two gears showing the base, pitch and addendum circles and the path of contact. (20)
- (b) The stiffness of a close-coiled spring is such that it deflects 36 mm when an axial force of 10 N is applied on the end of the hook.
- Calculate the mass to be hung on the hook so that, when set vibrating, it will make one complete oscillation per second. The mass of the spring is 0.6 kg and the effect of this when vibrating is to be taken as equivalent to a mass on the end of the hook equal to one third of the mass of the spring.
 - Calculate also the maximum velocity and
 - maximum acceleration of the vibrating mass when initially displaced 12 mm from the position of equilibrium.
 - What is the natural frequency of a vibrating system?
 - Can you suggest an application for the approach indicated above in practice? (20)
3. (a) Two shaft A and D are in the same line (axes in one line). They are geared together through an intermediate parallel shaft carrying wheels B and C which mesh with the wheels on A and D respectively. Wheels A and B have a module of 4 mm and wheels C and D have a module of 9 mm. The number of teeth on any wheel is to be not less than 15 and the speed of D is to be about, but not greater than 1/12 the speed of A and the ratio each reduction in the same. Find

- (i) suitable number of teeth for the wheels
- (ii) the actual reduction and
- (iii) the distance of the intermediate shaft from the axes of the shafts A & D (centre distance). Indicate the configuration with a sketch.
- (iv) What is addendum modification related to correction of gears and when are they used in practice?

(Gear A is on shaft A and gear D is on shaft D)

(20)

- (b) The semi-circle angle of a cone clutch is 12.5° and the contact surfaces have a mean diameter of 80 mm. The coefficient of friction is 0.32.

- (i) What is the minimum torque required to produce slipping of the clutch for an axial force of 200 N?

If the clutch is used to connect an electric motor with a stationary fly wheel,

- (ii) what is the time needed to attain the full speed and
- (iii) the energy lost during slipping?

Motor speed is 900 rpm and the moment of inertia of the flywheel is 0.4 kg m^2 .

- (iv) What are the considerations in the selection of plate clutches and cone clutches?

(20)

SECTION B

5. (a) (i) What is High-Efficiency range or High-Economic range (Hi-E) in machining?
 (ii) Why is it called so?
 (iii) The results of machining steel with two grades of tool materials are given below:

Tool	Taylor's Exponent	Cutting speed for one-minute tool life, m/min.
A	0.20	100
B	0.25	120

What are the standard tool life equations for these two materials?

- (iv) For a 180 minute tool life, which tool is recommended and why?
- (v) If the tool grinding and changing time is 15 minutes, which cutting speed for the tool 'A' has to be chosen from the two available speeds, 45 m/min, 50 m/min ?

(20)

- (b) (i) What are the basic differences between arc welding and submerged arc welding?
 (ii) What are the inert gases generally used in inert gas arc welding?
 (iii) What is weld penetration and what is weld reinforcement?
 (iv) In MIG welding the power source characteristic is

$$V_p = 36 - \frac{1}{60}$$

and the arc characteristic is $V_a = 2I_a + 27$

where V_p and V_a voltage, I current, l_a arc length in mm.

Find the change in power of the arc if the arc length is changed from 2mm to 4 mm.

If the maximum current capacity of the power source is 360 amps, find the minimum arc length sustainable?

(20)

6. (a) (i) What is the difference between counter-boring and counter-sinking?
(ii) What are the basic differences between gear milling and gear hobbing?
(iii) What are the basic differences between facing at constant S-speed and facing at constant feed?
(iv) A surface 80mm x 160mm is rough machined using a face milling cutter of 150 mm diameter having 10 teeth. The cutter centre is off-set by 15 mm from the line of symmetry of the surface. Estimate the time to rough machine the surface, if the feed per tooth is 0.25 mm and a cutting speed of 20 m/min is employed.
(v) With 5 mm approach and 5 mm over-run what is the single pass feed time?
(vi) If tool axis is symmetrical with the job what happens to the machining time?

(20)

- (b) In the state of Bihar, in a particular region there are 5 coal mines which produce the following output at the indicated production costs:

Mine	Output m.tons/day	Production Cost units of 100 Rs. Per metric ton
1	120	25
2	150	29
3	80	34
4	160	26
5	140	28

Before the coal can be sold to the steel making units, it must be cleaned and graded at one of the 3 coal preparation plants. The capacities and operating cost of these 3 plants are as follows:

Plants	Capacity metric tons/day	Operating cost units of 100 Rs. per metric ton
A	300	2
B	200	3
C	200	3

All coal is transported by rail at a cost of Rs. 50 per metric ton kilometer and the distance in kilometers from each mine in the preparation plants are indicated below:

Preparation Plant	Distance kilometres to Mines				
	1	2	3	4	5
A	22	44	26	52	24
B	18	16	24	42	48
C	44	32	16	16	22

- Using a transportation model, determine how the output of each mine should be allocated to the three preparation plants to optimise cost.
- Are alternative approaches possible? If so, what is the logic of 1 allocation in these alternatives?
- What is degeneration and when can it happen?

(20)

7. (a)
- What do you understand by quality control by attributes and Q. C. by variables?
 - Where do you need a larger sample size in the above and why? 4 batches of products are inspected at 90 minute intervals and their percentage differences in weight from the nominal are given below.

Percentage differences on weights in samples			
Batch or Sample 1	Sample 2	Sample 3	Sample 4
1.2	0.6	0.6	2.1
1.8	0.3	1.5	0.6
1.5	0.3	1.0	0.6
0.9	0.0	0.0	2.7
0.3	0.6	1.9	2.7

Assume that normal process average variation is 0.9% and process standard deviation is 0.5%. Assume further that range U.C.L. is 5 times S.D. Plot the \bar{X} , R chart indicating the various control limits.

- Is the process under control? Any comments.

(20)

- (b) A company is producing a batch of five parts A, O, E, N and L using three machines X, W, M. All these parts are to be produced in the technological order X. M. W machines. The sum of the processing and set-up times, in minutes for these parts in each of these machines is given below.

Part	Time on Machine, Minutes		
	X	W	M
N	8	5	3
A	4	6	4
O	7	7	3
L	5	8	4
E	6	4	4

- Find the sequence in which parts to be produced to minimise total make span.
- Are there alternative sequences?
- Represent your schedule in the form of a Gantt chart with starting and ending timings. Neglect machine to machine shifting time.
- What are the machine utilization percentages for each machine if no other job is taken till the completion of this batch?

(20)