MECHANICAL ENGINEERING

Paper I

Time Allowed: Three Hours **Maximum Marks: 250**

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions:

*There are **EIGHT** questions divided in **TWO SECTIONS** and printed both in **HINDI** and in **ENGLISH**.*

*Candidate has to attempt **FIVE** questions in all.*

*Questions no. **1** and **5** are compulsory and out of the remaining, any **THREE** are to be attempted choosing at least **ONE** question from each section.*

The number of marks carried by a question/part is indicated against it.

Answers must be written in the medium authorized in the Admission Certificate which must be stated clearly on the cover of this Question-cum-Answer (QCA) Booklet in the space provided. No marks will be given for answers written in a medium other than the authorized one.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Diagrams /Figures, wherever required, shall be drawn in the space provided for answering the question itself.

Unless otherwise mentioned, symbols and notations carry their usual standard meanings.

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

SECTION—A

Q1. (a) A 600 N cylinder is supported by the frame BCD as shown in the Figure 1(a). The frame is hinged at D. Determine the reactions at A, B, C and D.

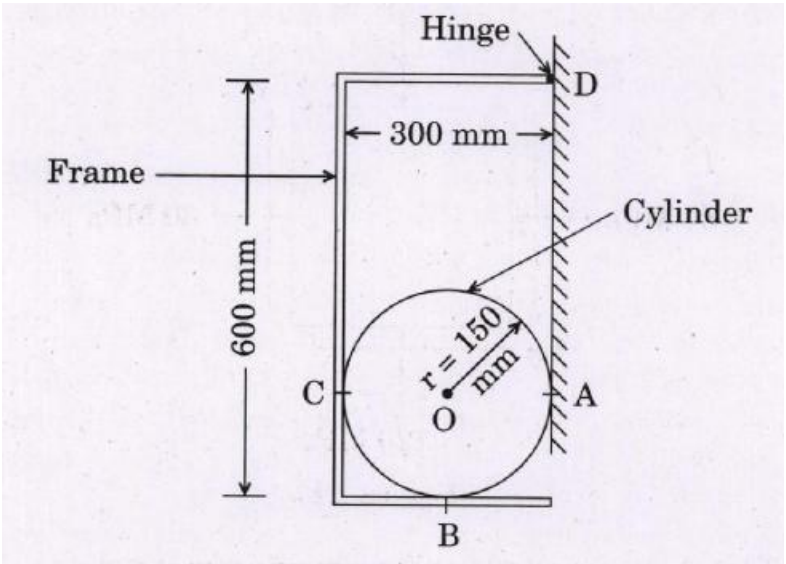


Figure 1(a) 10

(b) Find the complementary shear stress for the element with stresses as shown in Figure 1(b) given below. The major principal stress is 120 MPa. What is the magnitude of maximum shear stress and minimum principal stress? Also, locate the principal planes and maximum shear stress planes.

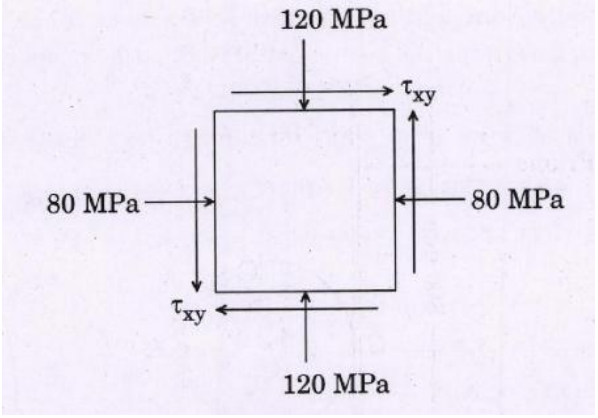


Figure 1(b) 10

(c) What are the factors affecting critical cooling rate? 10

(d) In a tensile test on a steel tube, outside diameter of 18 mm and inside diameter of 12 mm, an axial load of 12 kN produces a stretch of 3.5375×10^{-3} mm, on a length of 50 mm and a lateral contraction of outer diameter of 3.18375×10^{-4} mm. Calculate all the four elastic constants. 10

(e) The turning-moment diagram for a petrol engine is drawn to a vertical scale of 1 mm = 500 Nm and a horizontal scale of 1 mm = 3°. The turning-moment diagram repeats itself after every half revolution of the crank shaft. The areas above and below the mean torque line are + 270, – 590, + 100, – 390, + 870 and – 260 mm^2. The rotating parts have a mass of 50 kg and radius of gyration of 2.2 m. If the engine speed is 1500 rpm, determine the coefficient of fluctuation of speed. 10

Q2. (a) For the single overhanging beam as shown in Figure 2(a), draw the Shearing Force and Bending Moment diagram, if q × 2 L = 3 P. Also find the maximum Bending Moment and its location. Also locate the point of contraflexure.

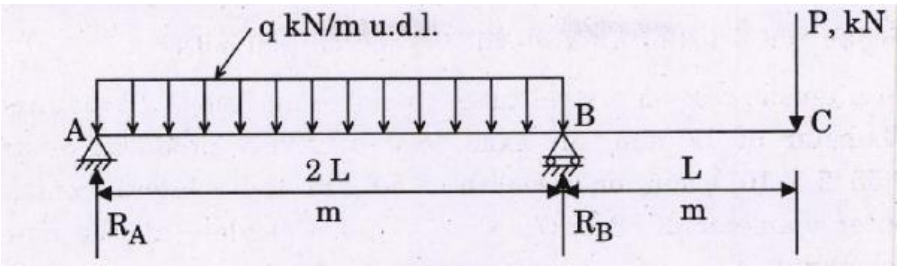


Figure 2(a) 20

(b) What is the value of P in the system as shown in Figure 2(b) to cause the motion to impend? Assume the pulley smooth and coefficient of friction, μ = 0.2 between the other contact surfaces.

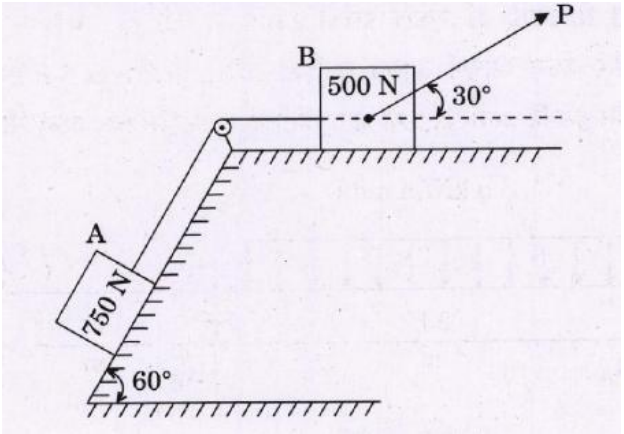


Figure 2(b) 15

(c) (i) A kinematic link may consist of many resistant bodies having no relative motion between them. Explain this statement considering the mechanism used in an internal combustion engine.

(ii) Explain, with the help of a neat sketch, the equivalent lower-pair mechanism of a cam-translating follower mechanism.

(iii) Some four-bar linkages are shown in Figure 2(c), where the number indicates the respective link length (in cm). Identify the nature of each mechanism i.e. whether it is

A. double crank,

B. crank-rocker, or

C. double rocker.

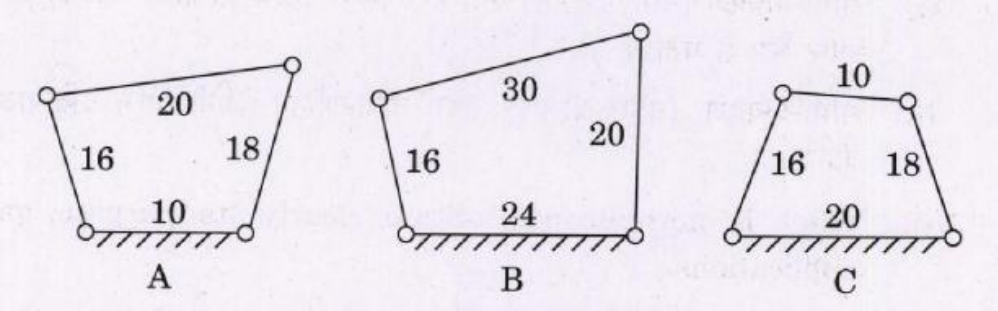


Figure 2(c) 15

Q3. (*a*) For the beam as shown in Figure 3(a) given below, if P = 1 kN and L = 1 m, determine the deflection at overhanging end C. The beam is of rectangular cross-section 120 mm x 240 mm (depth) and coefficient of elasticity, E = 200 GPa.

Given: $q \times 2L = 3P$.

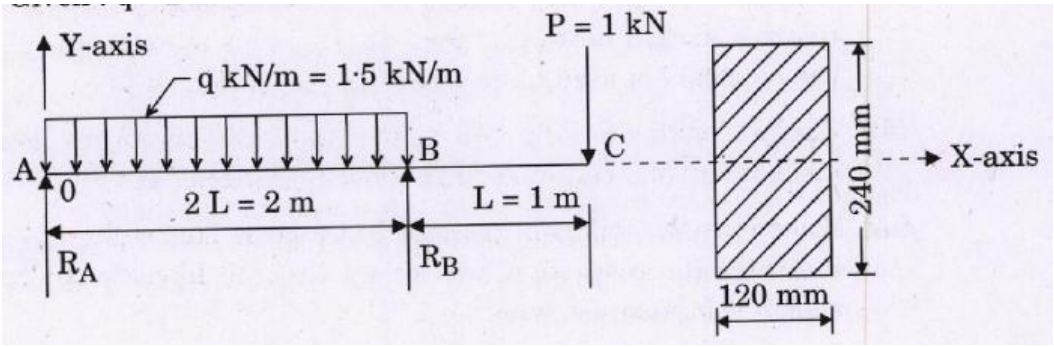


Figure 3(a) 20

(*b*) (i) What is normalizing? State clearly its purpose, process and applications.

(ii) Compare normalizing and annealing processes. 15

(*c*) In an epicyclic gear train, gear A has 15 teeth and is rigidly fixed to the motor shaft. The gear B has 20 teeth and meshes with A and also with fixed wheel D which has 55 teeth. Gear C has 15 teeth and is integral with B. Gear C meshes with gear E which is keyed to the machine shaft. The gear E has 50 teeth. The arm rotates about the same axis on which A is mounted and carries the compound wheels B and C. Arrangement is shown in Figure 3(c) given below. If the motor runs at 1000 rpm, find the speed of the machine shaft.

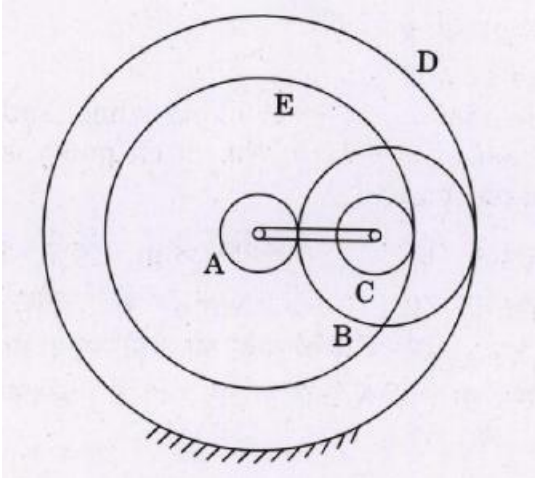


Figure 3(c) 15

Q4. (a) Two gear wheels having 20 and 40 teeth (involute) are in a mesh.
Given:

Pressure angle = 22.5°

Module =12 mm

Determine the addendum for each gear wheel and the contact ratio if the line of contact on each side of the pitch point is half of the maximum possible length on that side. 20

(b) A thin cylindrical shell is 3 m long, 1 m in diameter, thickness of wall is 10 mm. The internal fluid pressure is 1.5 N/mm^2. Calculate the change in dimensions of the shell and hence change in its volume. Also calculate the maximum intensity of shear stress. Given: E = 200 GPa and ν = 0.3. 15

(c) A circular cylinder of mass 4 kg and radius 15 cm is connected by a spring of stiffness 4000 N/m as shown in Figure 4(c) given below. It is free to roll on a horizontal rough surface without slipping. Determine the natural frequency.

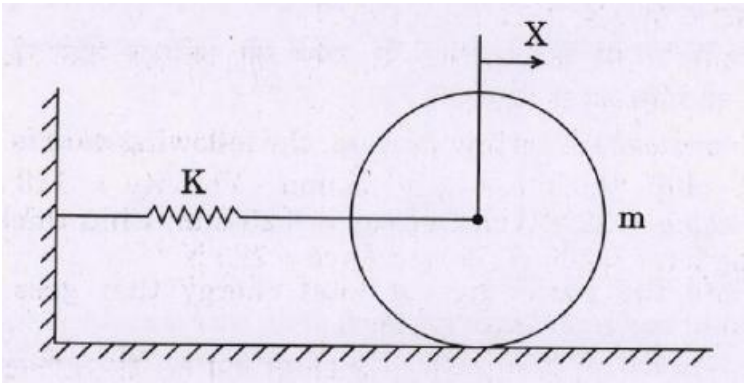


Figure 4(c) 15

SECTION B

Q5. (a) For an orthogonal cutting process, the following data is given:
Uncut chip thickness = 0.125 mm, Velocity = 110 m/min,
Rake angle = 12°, Width of cut = 6.25 mm, Chip thickness = 0.28 mm,
Cutting force = 550 N, Thrust force = 225 N
Calculate the percentage of total energy that goes into overcoming friction at the tool-chip interface. 10

(b) A cloth merchant has an average demand of 50 jeans per day with a standard deviation of 4 jeans per day. The average lead time of supply of jeans is 7 days

and standard deviation of lead time is 2 days. Calculate the ROL (Reorder Level) with 95% service level. (Given Z at 95% = 1.65) 10

(c) (i) Differentiate the applications of control charts for variables and control charts for attributes.

(ii) Define the term Process Capability Index and show the range of values of capability index for process under control and out of control showing the relationship with specification limits and process spread. 10

(d) Write the effect of various machining parameters on Material Removal Rate (MRR) in the case of Ultrasonic Machining (USM). 10

(e) (i) Write the major components of TQM philosophy.

(ii) How do you incorporate the seasonal variations in demand forecasting? 10

Q6. (a) An assembly line is to produce 180 units per 8-hour shift. The following table identifies the work elements, times, immediate predecessors: 20

Work Element	Time (Seconds)	Immediate Predecessors)
A	45	None
B	70	A
C	35	D, E, F
D	30	B
E	25	B
F	20	B
G	110	A
H	140	G
I	130	H
J	120	C,I

(i) Find the desired cycle time.

(ii) Find the theoretical minimum number of workstations required.

(iii) Draw the precedence diagram.

(iv) What are the efficiency and balance delays of the solution found?

(b) A company has narrowed the search for a new facility location to four places A, B, C and D. The estimated fixed costs/annum and variable cost/unit at the locations are given in the table below : 20

Location	Fixed costs per annum (in Rs)	Variable costs per unit (in Rs)
A	9,00,000	300
B	15,00,000	150
C	25,00,000	125
D	30,00,000	110

(i) Plot the total cost curves for all the four locations on single graph. Identify on the graph the approximate range over which each location provides the lowest cost.

(ii) If the expected demand is 12,000 units per year, what is the best location?

(c) Two tool materials, X and Y have been selected for the machining of a workpiece. The data obtained for both the materials are shown in the table given below: 10

Tool materials	Tool life (minutes)	Cutting speed (metres/minute)
X	25	100
	10	150
Y	40	200
	20	250

Estimate the relative machinability, considering material X as standard material and tool life of 50 minutes as criteria.

Q7. (a) A tube of 18 mm outside diameter and 1.6 mm wall thickness is to be drawn to an outside diameter of 12 mm and wall thickness of 1 mm using a plug. Calculate the drawing load, given that coefficient of friction for die = 0.16 and for the plug = 0.2. The die angle is 30° and the plug angle is 20°. The metal is in fully work hardened condition with a yield stress of 1.4 kN/mm^2. Also find the power rating of the motor if the drawing speed is 0.6 m/sec. 20

(b) Under the orthogonal cutting operation of a workpiece of aluminum, the forces determined by the dynamometer F_C and F_T are 1500 N and 1000 N respectively. Rake angle of the tool is 10°. Chip thickness ratio is 0.37. Determine F_N, F_S, N and F using Merchant's theory. Also determine the coefficient of friction at the chip-tool interface.

(Here F is the force along the rake surface; N is the force acting perpendicular to the rake surface, F_C is the cutting force; F_T is the tangential force and perpendicular to F_C; F_S is the shear force and F_N is the normal component of shear force). 20

(c) Arrange the following jobs on Machine 1 to Machine 5 using the Johnson's rule of sequencing. The time (in minutes) required by the jobs on these machines are shown in the table given below. Also find the total idle time and completion time of the jobs. 10

Jobs	Machine 1	Machine 2	Machine 3	Machine 4	Machine 5
A	7	5	2	3	9
B	6	6	4	5	10
C	5	4	5	6	8
D	8	3	3	2	5

Q8. (a) The voltage - length characteristics of a direct current arc is given by

$$V = (22 + 40l) \text{ Volts},$$

where l is the length of the arc in cm. The power source characteristic is approximated by a straight line with an open circuit voltage = 80 V and short circuit current = 1000 amp. Determine the optimum arc length and corresponding power. 20

(b) The time estimates in weeks for the activities of a PERT network are given in the table below: 20

Activity	Optimistic time (t_0)	Most likely time (t_m)	Pessimistic time (t_p)
1-2	1	1	7
1-3	2	5	8
1-4	2	2	8
3-5	3	6	15
4-5	1	4	7
5-6	2	5	14
2-6	2	5	8

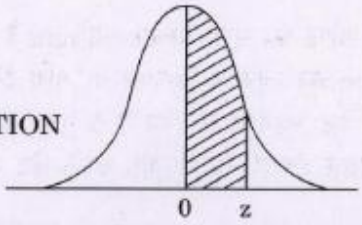
(i) Draw network diagram and determine project completion time.

(ii) Find the probability that the project will be finished in between 15th to 20th week of the scheduled completion.

(iii) Find the probability that the project will be finished no more than 2 weeks later than the expected completion time.

(The standard normal distribution chart is given in the question)

AREAS UNDER THE STANDARD NORMAL PROBABILITY DISTRIBUTION



Values in the table represent the proportion of area under the normal curve between the mean ($\mu = 0$) and a positive value of z.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2703	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990

(c) A hole and shaft have a basic size of 25 mm and are to have a clearance fit with maximum clearance of 0.02 mm and a minimum clearance of 0.01 mm. The hole tolerance is to be 1.5 times of the shaft tolerance. Determine the limits for both hole and shaft (i) using hole basis system and (ii) using shaft basis system. 10

MECHANICAL ENGINEERING

Paper II

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SECTION A

1. (*a*) Water is pumped from the basement tank of a multistorey building to the terrace tank by a 20 kW motor. The free surface of the terrace tank is 45 m higher than the basement tank. If the flow rate of water is 0.03 m^3/s, determine the mechanical power that is converted to thermal energy during the process due to friction effect. Write the assumptions made in the calculation. 10

(*b*) Show that for a supersonic isentropic flow, an increase in flow area is accompanied by an increase in flow velocity and a decrease in pressure. 10

(*c*) An ideal simple gas turbine cycle is having a pressure ratio of r and a temperature ratio, defined as the ratio of maximum temperature to minimum temperature in the cycle, of t, and the ratio of specific heats of γ. Show that the specific work output is maximum when the pressure ratio is such that the compressor outlet and turbine outlet temperatures are equal. Also, derive expressions for the two pressure ratios as functions of t and γ, where the specific output becomes zero for a constant temperature ratio. Draw the *T-s* diagram and a sketch of the layout of the components. 10

(*d*) A furnace wall consists of 200 mm inner layer of refractory brick (fc = 1-52 W/m-K), 8 mm thick steel plate (fc = 45 W/m-K) and outer layer of 100 mm thick insulation brick (fc = 0-138 W/m-K). The inner wall of the furnace is maintained at 1150 °C, while the outer wall of the insulation brick is at 40 °C. Calculate the heat transfer through the wall. What is the temperature at the junction of steel plate and outer insulation brick wall? 10

(*e*) Liquid mercury flows at a rate of 1.25 kg/s through a copper tube of diameter 20 mm. Mercury enters the tube at 20°C and leaves the tube at 30°C.

Calculate the tube length for constant heat flux at the wall which is maintained at an average temperature of 40°C. The empirical correlation for heat transfer for liquid metal flowing through a tube is given as

$$Nu = 7 + 0.025(Pe)^{0.8},$$

where Pe is Peclet number, Pe = Pr.Re.

The properties of mercury at 25°C are as follows:

$\rho = 13582$ kg/m^3

$C_P = 140$ J/kg-K

$k = 8.69$ W/m-K

$\nu = 1.5 \times 10^{-7}$ m^2/s

Pr = 0.0248 10

2. (*a*) (i) A 40 litres electrical radiator (heater) containing heating oil is placed in a 50 m^3 room. Both the room and the oil in the radiator are initially at 10°C. The radiator with a rating of 2.4 kW is now turned on. At the same time, heat is lost from the room at an average rate of 0.35 kJ/s. After some time, the average temperature for air in the room is 20°C and the oil in the radiator is 50°C. Take the density and the specific heat of the oil to be 950 kg/m^3 and 2.2 kJ/kg-K respectively. Determine how long the heater is kept on. Assume the room is well-sealed and ambient pressure is 1 bar. 10

(ii) Why are the temperature and pressure dependent properties in the saturated mixture region of pure substance? What is the difference between critical point and triple point? 10

(*b*) A 45° reducing pipe-bend in a horizontal plane, tapers from 600 mm diameter at inlet to 300 mm diameter at outlet. The gauge pressure at inlet is 140 kPa and the rate of flow of water through the bend is 0.425 m^3/s. Neglecting friction, calculate the net resultant horizontal force exerted by the water on the bend. 20

(*c*) A 1 mm diameter electric wire is covered with 2 mm thick layer of insulation (k = 0.5 W/m-K). Air surrounding the wire is at 25°C and h = 10 W/m^2-K. The wire temperature is 100°C. Find the rate of heat dissipation from the insulated wire per unit length. Also, find the maximum value of heat dissipation per unit length for the corresponding critical thickness of insulation. 10

3. (*a*) In an industrial gas turbine plant, the air leaving a single-sided centrifugal compressor enters the combustion chamber. The hot gases leaving the combustion chamber undergo expansion in a single-stage gas turbine. The compressor is required to deliver 14 kg of air per second, when operating at a (total to total) pressure ratio of 4 : 1 and a speed of 12000 r.p.m. The total head inlet conditions may be taken as 25°C and 1.0 bar. Assuming a slip factor of 0.9, a power input factor of 1.04 and an isentropic efficiency (based on total head) of 80%, estimate the overall diameter of the impeller. Assume no pre-whirl. If the Mach number at the impeller tip is not to exceed unity and 50% of the losses are assumed to occur in the impeller, find the minimum possible depth of the diffuser. Also, draw a sketch of the compressor, clearly showing the impeller and the diffuser. Draw the corresponding *T-s* diagram also. 20

(*b*) A counterflow double-pipe heat exchanger is used to heat glycerin from 20°C to 50°C by hot water, which enters the thin-walled 2 cm diameter tubes at 80°C and leaves at 40°C. The total length of the heat exchanger is 60 m. The convection heat transfer coefficient is 25 W/m^2-K on the glycerin side (in the annulus) and 160 W/m^2-K on the water side (in the inner tube). Determine the rate of heat transfer in the heat exchanger (i) before any fouling and (ii) after fouling with a fouling factor of 0.0006 m^2-K/W occurred on the glycerin side of the inner tube. The thermal resistance of the inner tube is negligible. 20

(*c*) A Carnot refrigeration cycle is operating between the minimum and maximum temperatures of –8°C and 20°C respectively. The refrigerant used in the cycle is R-134a and the cycle is operating in the saturated liquid-vapour region. The mass of the refrigerant is 0.8 kg and the refrigerant is saturated liquid at the end of heat rejection process. The net work input to the cycle is 15 kJ. Determine the fraction of the mass of the refrigerant that vaporizes during the heat addition process. Given

h_{fg} at –8°C = 204.59 kJ/kg

h_{fg} at 20°C = 180.33 kJ/kg 10

4. (*a*) With the help of continuity, momentum and energy equations, obtain an expression for Mach number after a normal shock in terms of the Mach number before the shock. 20

(*b*) Define degree of reaction for a stage of an axial flow compressor and derive an expression for the same in terms of the fluid angles and the blade angles. Show that when the degree of reaction is 50%, the velocity triangles are symmetrical. Consider a stage of an axial flow compressor with degree of reaction equal to 50% and isentropic efficiency (based on total head) is less than 100% in both the rotor and the stator blades. Draw the T-s diagram and velocity triangles for this stage. Show in the form of a table, how the following flow parameters change in the rotor and the stator of the stage:

(i) Absolute velocity
(ii) Relative velocity
(iii) Stagnation pressure
(iv) Static pressure
(v) Stagnation temperature
(vi) Static temperature 20

(*c*) Daylight and incandescent light may be approximated as blackbody emissions at the effective surface temperatures of 5800 K and 2800 K, respectively. From the principles of radiation, show that incandescent lightbulbs are inefficient as light sources in the visible spectrum wavelength range of 0.40 μm to 0.76 μm. The blackbody radiation function, f_λ as a function of λT (μm-K) given in the table may be used. The blackbody radiation function, f_λ represents the fraction of radiation emitted from a blackbody at temperature T in the wavelength band from $\lambda = 0$ to λ, to the total radiation energy emitted by the blackbody in the wavelength range 0 to ∞.

Blackbody radiation function, f_λ

λT (μm-K)	f_λ	λT (μm-K)	f_λ
200	0.000000	6200	0.754140
400	0.000000	6400	0.769234
600	0.000000	6600	0.783199

800	0.000016	6800	0.796129
1000	0.000321	7000	0.808109
1200	0.002134	7200	0.819217
1400	0.007790	7400	0.829527
1600	0.019718	7600	0.839102
1800	0.039341	7800	0.848005
2000	0.066728	8000	0.856288
2200	0.100888	8500	0.874608
2400	0.140256	9000	0.890029
2600	0.183120	9500	0.903085
2800	0.227897	10000	0.914199
3000	0.273232	10500	0.923710
3200	0.318102	11000	0.931890
3400	0.361735	11500	0.939959
3600	0.403607	12000	0.945098
3800	0.443382	13000	0.955139
4000	0.480877	14000	0.962898
4200	0.516014	15000	0.969981
4400	0.548796	16000	0.973814
4600	0.579280	18000	0.980860
4800	0.607559	20000	0.985602
5000	0.633747	25000	0.992215
5200	0.658970	30000	0.995340
5400	0.680360	40000	0.997967
5600	0.701046	50000	0.998953
5800	0.720158	75000	0.999713
6000	0.737818	100000	0.999905

10

SECTION – B

5. (*a*) What are the desired properties of lubricants used in IC engines? How do different additives help to achieve these desired properties? 6+4=10

(*b*) Determine the height of a chimney to produce a static draught of 20 mm of water. The mean hot gas temperature in the chimney is 270°C and the atmospheric air temperature is 20°C. Take atmospheric pressure as 0.101325 MPa. The characteristic gas constant for air is 287 J/kg-K and for chimney gas, it is 255 J/kg-K. 10

(*c*) (i) Enumerate the desirable properties of refrigerant-absorbent pairs for vapour absorption refrigeration system. 5

(ii) What are the drawbacks of presence of water vapour in the evaporator and condenser of an aqua-ammonia absorption refrigeration system? 5

(*d*) Briefly explain different methods for the use of alcohols as alternate fuel in SI engines. Also, write the merits and demerits of alcohol as fuel. 10

(*e*) Atmospheric air at 1.033 bar and 35°C DBT and 60% RH is undergoing a psychrometric process. During the process, the specific humidity of air is reduced by 5 gm/kg of dry air and the DBT of air is reduced to 25°C, while the pressure is maintained constant. Determine the relative humidity and dew-point temperature of air in the final condition. Solve the problem using only psychrometric relations.

Saturated Water-Temperature Table

Temperature T(°C)	Saturated Pressure P_{sat} (kPa)
0.1	0.6117
5	0.8725
10	1.2281
15	1.7057
20	2.3392
25	3.1698
30	4.2469
35	5.6291
40	7.3851
45	9.5953

10

6. (*a*) A Parson's turbine runs at 400 r.p.m. and it develops 75 kW of power per unit mass of steam flow per second. The exit angle of the blades is 20° and the steam velocity is 1.4 times the blade velocity. Find the blade velocity and the inlet angle of the blades. 20

(*b*) A four-cylinder, four-stroke SI engine has an output of 80 kW at 3000 r.p.m. A Morse test is carried out and the brake torque readings are 175 N-m, 170 N-m, 174 N-m and 172 N-m, respectively. The specific fuel consumption for normal running at this engine speed is 0.385 kg/kWh. The calorific value of fuel is 44000 kJ/kg. Calculate the mechanical and brake thermal efficiencies of the engine. 20

(*c*) Explain how a simple capillary tube works as an expansion device in vapour compression refrigeration system. What are the advantages and disadvantages of capillary tube as an expansion device? 10

7. (*a*) A hall is to be maintained at 24°C DBT and 60% RH, when the following data are given:

Outdoor conditions : 38°C DBT and 28 °C WBT
Sensible heat load in the room : 160000 kJ/hr
Latent heat load in the room : 40000 kJ/hr
Total infiltrated air : 1200 m^3/hr
Apparatus dew-point temperature : 10°C

The quantity of recirculated air from the hall is 60% of total. If the recirculated air is mixed with the conditioned air after the cooling coil, then find the following :

(i) The condition of air leaving the cooling coil and before mixing with the recirculated air
(ii) Condition of air before entering the hall
(iii) The mass of air entering the the hall
(iv) Bypass factor of the cooling coil
(v) The total mass of air supplied to the hall
(vi) The refrigeration load on the cooling coil in TR

Draw a sketch of the layout and show the process on a typical psychrometric plot. Use of psychrometirc chart data is permitted. 20

(*b*) (i) State the major advantages and disadvantages of combined gas and

steam turbine power plants. 10

(ii) Compare the thermal efficiencies of two boilers having the following data:

Boiler 1 (Coal-fired)
- Steam pressure — 1.4 MPa
- Steam produced/kg of coal fired — 10 kg
- Quality of steam — 0.9
- Feed water temperature — 27°C
- Calorific value of coal — 34000 kJ/kg

Boiler 2 (Oil-fired)
- Steam pressure — 1.4 MPa
- Steam produced/kg of oil fired — 14 kg
- Condition of steam (superheated) — 240°C
- Feed water temperature — 27°C
- Calorific value of oil — 46000 kJ/kg

Use the following data:

At 1.4 MPa for steam—

$h_{\text{Superheated}}$ = 2903 kJ/kg at 240°C

h_f = 830 kJ/kg

h_{fg} = 1958 kJ/kg

Specific heat of feed water = 4.1868 kJ/kg-K 10

(*c*) (i) Explain knocking in SI engines with the help of a p-θ diagram. 6

(ii) Discuss the effect of compression ratio and inlet gas temperature on knocking in SI engines. 4

8. (*a*) A simple vapour compression refrigeration cycle using Freon 22 is designed for a load of 100 TR. The saturation temperatures in the evaporator and condenser are 5°C and 40°C respectively. The refrigerant leaves the evaporator and enters the compressor as saturated vapour. The refrigerant leaves the condenser and enters the expansion device as subcooled liquid with a subcooling of 5°C. The specific heat of the vapour is 0.65 kJ/kg-K and the specific heat of the liquid is 1.1 kJ/kg-K for the refrigerant. Calculate (i) the mass flow rate (kg/s) of the refrigerant, (ii) the COP and isentropic compressor power and (iii) the heat rejected in the condenser.

Use the following data :

T_{sat} (°C)	P_{sat} (bar)	h_f (kJ/kg)	h_g (kJ/kg)	s_f (kJ/kg-K)	s_g (kJ/kg-K)	v_g (m^3/kg)
5	5.836	205.9	407.1	1.02115	1.7447	0.0404
40	15.331	249.53	416.4	1.16659	1.69953	—

20

(*b*) (i) Explain the variation of pressure along the axis of a convergent-divergent nozzle operating off the design pressure ratio. 10

(ii) Discuss the principle of bypass governing in a steam turbine with neat sketches. 10

(*c*) An engine working on ideal diesel cycle has a compression ratio of 15 : 1. The temperature of air at the beginning of the compression stroke is 27°C and the air-fuel ratio used is 35 : 1. Find the air-standard efficiency of the cycle. The calorific value of the fuel is 42000 kJ/kg. 20

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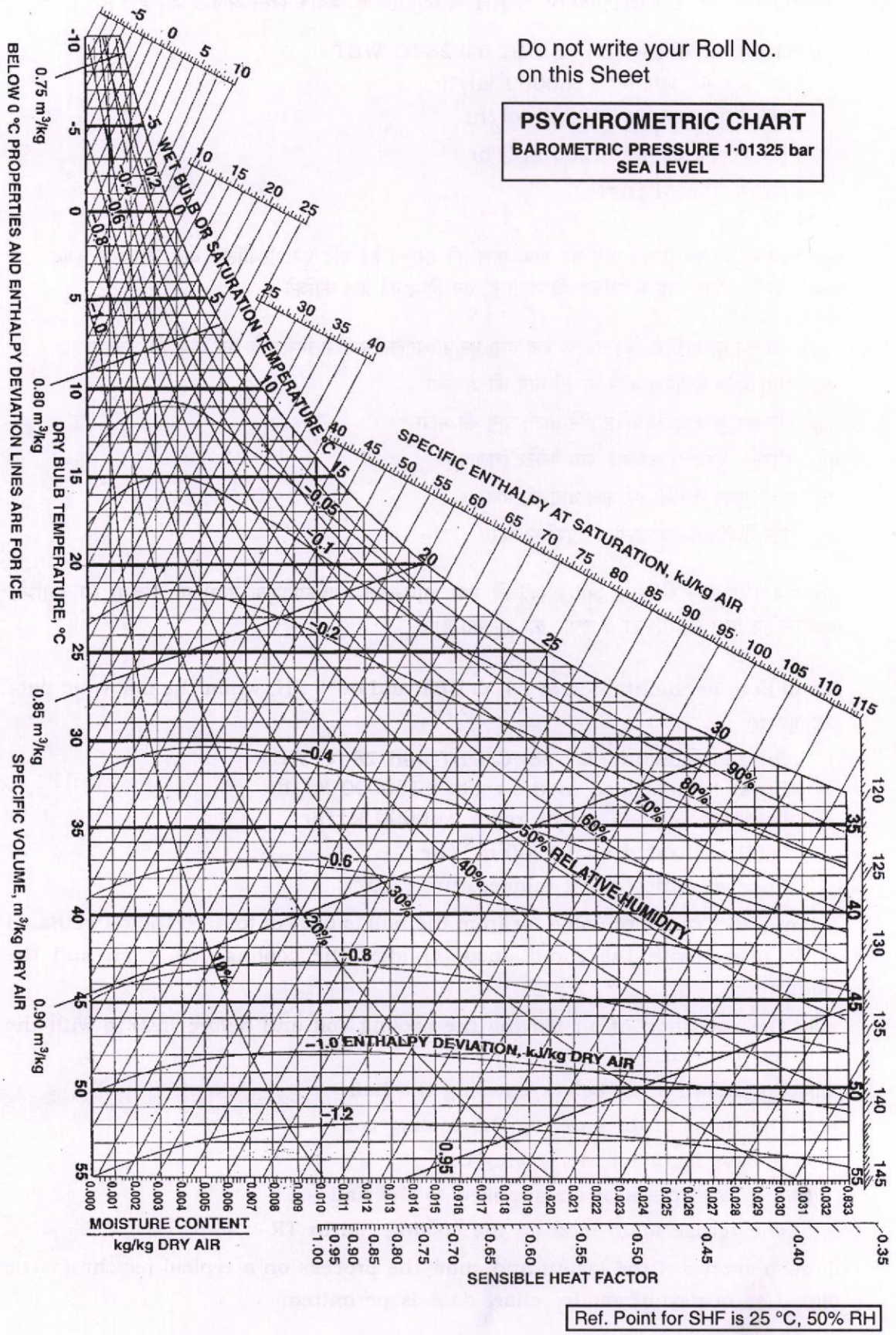

Ref. Point for SHF is 25 °C, 50% RH