MECHANICAL ENGINEERING Paper I

Time Allowed: Three Hours **Maximum Marks: 300**

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions

There are EIGHT questions in all, out of which FIVE are to be attempted.
Question Nos. **1** and **5** are compulsory. Out of the remaining SIX questions, THREE are to be attempted selecting at least ONE question from each of the two Sections A and B.
The number of marks carried by a question/part is indicated against it.
Unless otherwise mentioned, symbols and notations have their usual standard meanings.
Assume suitable data, if necessary and indicate the same clearly.
Neat sketches may be drawn, wherever required.
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.
Answers must be written in ENGLISH only.

SECTION—A

1. (*a*) What are meant by killed steels and rimmed steels? Explain the characteristics of these steels. Enlist its applications. 8

(*b*) A flat belt transmits 10 kW power at a speed of 5 m/s. The mass of the belt is 1.5 kg/m and the angle of lap at smaller pulley is 200°. The coefficient of friction between the belt and the pulley is 0.330. Determine the initial tension in the belt. 8

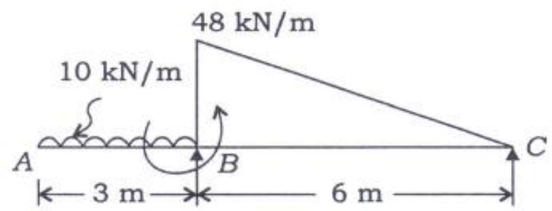
(*c*) Compare between involute and cycloidal gear tooth profiles. List the important properties of a good material for sliding contact bearing. 8

(*d*) A compound bar is constructed from three bars 50 mm wide by 12 mm thick fastened together to form a bar 50 mm wide by 36 mm thick. The middle bar is of aluminium alloy for which $E = 70 \times 10^9$ N/m^2 and the outside bars are of brass with $E = 100 \times 10^9$ N/m^2. If the bars are initially fastened at 18°C and the temperature of the whole assembly is then raised to 50°C, determine the stresses set up in the brass and the aluminium alloy. Take the coefficient of expansion of the brass (α_B) and the aluminium alloy (α_A) as follows :

$$\alpha_B = 18 \times 10^{-6} \text{ per °C and } \alpha_A = 22 \times 10^{-6} \text{ per °C}$$ 8

(*e*) State the difference between elastic and plastic deformation. Explain each in detail. 8

2. (*a*) A beam *ABC* is 9 m long and supported at *B* and *C*, 6 m apart as shown in the figure below. The beam carries a triangular distribution of load over the portion *BC* together with an applied counterclockwise couple of moment 80 kN-m at *B* and a uniformly distributed load of 10 kN/m over *AB*. Draw the shear force and bending moment diagrams for the beam:



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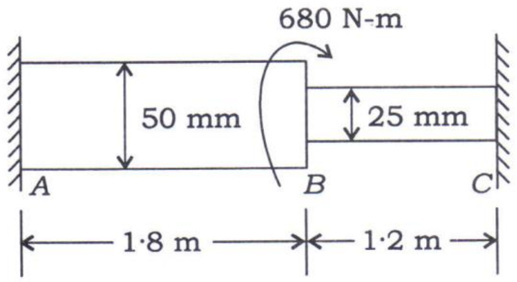
(*b*) Determine the load required to produce an extension of 8 mm on an open-coiled helical spring of 10 coils of mean diameter 76 mm, with helix angle of 20° and manufactured from wire of 6 mm diameter. What will then be the bending and shear stresses in the surface of the wire? For the material of the spring, $E = 210 \times 10^9$ N/m^2 and $G = 70 \times 10^9$ N/m^2. What would be the angular twist at the free end of the above spring when subjected to an axial torque of 1.5 N-m? 15

(*c*) The lines of strokes of a three-cylinder radial engine are 120° apart. The length of each connecting rod is 250 mm and the crank radius is 75 mm. The reciprocating parts have a mass of 2.5 kg per cylinder. Determine the primary and secondary forces if the engine runs at 2000 r.p.m. 15

3. (*a*) A circular bar *ABC*, 3 m long is rigidly fixed at its ends *A* and *C*. The portion *AB* is 1.8 m long and of 50 mm diameter and *BC* is 1.2 m long and of 25 mm diameter. If a twisting moment of 680 N-m is applied at *B*, determine the values of the resisting moments at *A* and *C*, and the maximum stress in each section of the shaft. What will be the angle of twist of each portion? Take the value of *G* for the shaft material as 80×10^9 N/m^2. The appearance of the shaft (bar) is shown in the figure below:



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(*b*) What is meant by atomic packing factor? Calculate atomic packing factor for the following cases :

(i) Simple cubic

(ii) Body-centred cubic

(iii) Face-centred cubic 15

(*c*) A Hartnell governor has equal balls of mass 3 kg, set initially at a radius of 200 mm. The arms of the bell crank lever are 100 mm vertically and 150 mm horizontally. Find—

(i) the initial compressive force on the spring if the speed for an initial ball radius of 200 mm is 300 r.p.m.;

(ii) the spring stiffness required to permit a sleeve movement of 5 mm on a fluctuation of 10% in the engine speed. 15

4. (*a*) Define the term hardenability of steel. What factors affect hardenability? Name any three methods for determining the hardenability of steel. 10

(*b*) At a point in a piece of elastic material, direct stresses of 90×10^6 N/m^2 tensile and 50×10^6 N/m^2 compressive are applied on mutually perpendicular planes. The planes are also subjected to shear stress. If the greater principal stress is limited to 100×10^6 N/m^2 tensile, determine—

(i) the value of the shear stress;

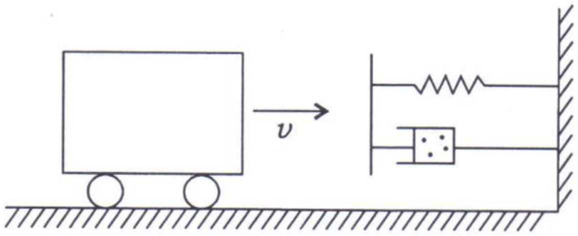
(ii) the other principal stress;

(iii) the normal stress on the plane of maximum shear;

(iv) the maximum shear stress.

Make a neat sketch showing clearly the positions of the principal planes and planes of maximum shear stress with respect to the planes of applied stresses. 15

(*c*) A railroad car of mass 2000 kg travelling at a velocity v = 10 m/s is stopped at the end by a spring-damper system as shown in the figure below. The stiffness of the spring is 40 kN/m and the damping coefficient is 20 N-s/mm. Determine the maximum displacement of the car after engaging the spring-damper system:



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SECTION—B

5. (*a*) What is the principle of Plasma Arc Machining? Explain with the help of a neat sketch. 8

(*b*) During orthogonal machining with an HSS tool, the rake angle was 5°, the undeformed chip thickness was 0.25 mm and the width of cut was 4 mm. Taking the shear strength of the work material to be 350 N/mm² and the coefficient of friction between the chip and the tool to be 0.5, estimate the cutting force and the thrust force. 8

(*c*) What are control charts and where are they used?
Draw the control charts for mean X and range R from the following data relating to the thickness of a job, by taking 5 samples from a lot of 100 and 6 lots are checked. Comment whether it is in statistical control or not.
(Given : For sample of size 5; $D_3 = 0$, $D_4 = 2.115$ and $A_2 = 0.577$)

Lot → Sample ↓	1	2	3	4	5	6
1	7	6	8	5	4	2
2	8	5	7	4	6	3
3	5	4	5	3	2	1
4	4	3	2	3	1	5
5	6	1	4	2	5	6

8

(*d*) In time series analysis of forecasting, explain the terms demand noise, pattern and stability.
Demand for a particular product was 500 in April, 350 in May and 600 in June. The forecast for April was 250 units. With a smoothing constant of 0.15 and using first-order exponential smoothing, find the July forecast. 8

(*e*) Differentiate between RAM and ROM, and also discuss different types of RAM and ROM. 8

6. (*a*) The number of identical components produced at different spindle speeds and feeds between consecutive tool changes in a single-pass turning operation is given in the table below:

Spindle speed (r.p.m.)	300	300	400

Feed (mm/rev)	0.100	0.125	0.125
Number of components produced	300	250	150

Estimate the number of components that can be produced at a spindle speed of 500 r.p.m. and a feed of 0.20 mm/rev. 15

(*b*) Define the term automation. Differentiate between the types of automation with examples. 10

(*c*) *(i)* Differentiate between the following :

(1) Job design and Job rotation

(2) Job enlargement and Job enrichment 10

(ii)

(*d*) An industrial engineer conducted a direct time study for an acid mixing operation. The analyst found cycle times as shown below, rated the observed worker at 80 percent, and used the firm's 0.10 allowance fraction:

Cycle time (in minutes)	2.7	2.7	2.9	3.1	3.2
Number of times observed	3	4	2	1	1

Determine the standard time. 5

7. (*a*) A company has three plants at locations P_1, P_2 and P_3 which supply warehouses W_1, W_2, W_3, W_4 and W_5. The monthly plant capacities are 800 units, 500 units and 900 units respectively. The monthly warehouse requirements are 400 units, 350 units, 300 units, 250 units and 900 units respectively. The unit transportation costs in rupees are given below:

Warehouse → Plant ↓	W_1	W_2	W_3	W_4	W_5
P_1	8	8	9	4	3
P_2	5	8	5	11	6
P_3	8	9	7	3	3

Determine an optimum distribution for the company in order to minimize the total transportation cost. How much is the cost? 15

(*b*) For a product, the purchase prices are given below:

SI. No.	*Order quantity (Q_i)*	*Unit price (Rs)*
1	1-49	20000
2	50-99	19000
3	100 or more	18000

Determine the optimum purchase quantity if the annual demand of the product is 400, the cost of placing an order is Rs 10000 and the inventory carrying cost is 20%. 15

(*c*) Differentiate between rolling and forging forming processes.

A strip with a cross-section of 160 mm × 7 mm is being rolled with 15% reduction of area, using 300 mm diameter steel rolls. Before and after rolling, the shear yield stresses of the material are 0.45 kN/mm and 0.50 kN/mm respectively. Calculate—

(i) the final strip thickness;

(ii) the average shear yield stress during the process;

(iii) the angle subtended by the deformation zone at the roll centre. 10

8. (*a*) The composition (% by weight) of a Monel alloy workpiece undergoing electrochemical machining is as given below :

Ni	Cu	Fe	Mn	Si	C
63	31.7	2.5	2	0.5	0.3

Calculate the removal rate (in cm^3/min) when a current of 1000 amperes is passed. Use the lowest valency of dissolution for each element.

Use the table given below for atomic weight, valency of dissolution and density of the above elements:

Elements	Ni	Cu	Fe	Mn	Si	C
Atomic weight	58.71	63.57	55.85	54.94	28.09	12
Valency	2/3	1/2	2/3	2/4/6/7	4	4
Density (gm/cm³)	8.90	8.96	7.86	7.43	2.33	3.5

15

(*b*) The annual demand for a manufacturing company is expected to be as follows:

Units demanded	10000	12000	14000	16000
Probability	0.4	0.3	0.2	0.1

Revenues are at Rs 30000/unit. The existing manufacturing facility has annual fixed operating costs of Rs 20,00,000.00. The variable manufacturing costs are Rs 7500/unit at the 10000 units output level; Rs 6000/unit at the 12000 units output level; Rs 5000/unit at the 14000 units output level and Rs 4500/unit at the 16000 units output level.

An expected facility under consideration would require Rs 25,00,000.00 fixed operating costs. The variable costs would average Rs 78.00/unit at the 10000 units output level; Rs 6300/unit at the 12000 units output level; Rs 4700/unit at the 14000 units output level and Rs 4200/unit at the 16000 units output level.

To maximize net earning, which size facility is to be selected? 15

(*c*) Write a C program to multiply two matrices whose elements are only integers, and print the result. 10

MECHANICAL ENGINEERING Paper II

Time Allowed: Three Hours **Maximum Marks: 300**

Question Paper Specific Instructions

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

*There are **EIGHT** questions in all, out of which **FIVE** are to be attempted.*
*Questions no. **1** and **5** are **compulsory**. Out of the remaining **SIX** questions, **THREE** are to be attempted selecting at least **ONE** question from each of the two Sections A and B.*
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.
All questions carry equal marks. The number of marks carried by a question/part is indicated against it.
*Answers must be written in **ENGLISH** only.*
Unless otherwise mentioned, symbols and notations have their usual standard meanings.
Assume suitable data, if necessary and indicate the same clearly. Neat sketches may be drawn, wherever required.
Newton may be converted to kgf using the equality 1 kilonewton (1 kN) — 100 kgf if found necessary.
All answers should be in SI units.
Take: 1 kcal = 4.187 kJ and 1 kg/cm² – 0.98 bar
1 bar = 10^5 pascals
Universal gas constant = 8314.6 J/kmol-K
Psychrometric chart is enclosed.

SECTION A

Q1. (a) A non-flow quasi-static process occurs for which P = – 3V + 16 bar, where V is the volume in m^3. What is the work done when V changes from 2 m^3 to 6 m^3? 8

(b) Air flows steadily at the rate of 1 kg/s through an air compressor. The properties of air at entry are velocity 7 m/s, pressure 105 kPa, specific volume 0.95 m^3/kg. The properties at exit are velocity 5 m/s, pressure 700 kPa, specific volume 0.19 m^3/kg. The internal energy of the air increases by 95 kJ/kg, as it flows through the compressor. Cooling water in the compressor jacket removes heat from the air at the rate of 60 kW.
(i) Compute the rate of shaft work input to the air, in kW.
(ii) Find the ratio of inlet pipe diameter to outlet pipe diameter. 8

(c) Define specific speed of a turbine. Derive its expression in terms of speed, power and head. 8

(d) Explain what you understand by Similitude. Further, explain the following: 8
(i) Geometric Similarity
(ii) Kinematic Similarity
(iii) Dynamic Similarity

(e) Sketch and describe a natural circulation high pressure boiler. 8

Q2. (*a*) A system at 500 K receives 7000 kJ/min from a source at 1000 K. The temperature of atmosphere is 300 K. Assuming that the temperature of the system and source remain constant during heat transfer, find out:
(i) The entropy produced during heat transfer

(ii) The decrease in available energy of source after heat transfer and increase in available energy of the system.

Show the process on the T-s diagram and mark the increase in unavailable energy. 20

(*b*) Twenty people attend a cocktail party in a small room which measures 9.1 m by 7.6 m and 2.4 m ceiling. Each person generates about 131 W of heat. Assuming that the room is completely sealed off and well insulated, calculate the air temperature rise occurring within 15 minutes if the room temperature is 21°C. Volume occupied by each person is 0.07 m^3. The atmospheric pressure is 1.01325 bar. Take C_v of the air as 718 J/kg K. 10

(*c*) Derive an equation describing a Fanno curve. Clearly mention the various assumptions made. Further, prove that at the maximum entropy point Mach number is unity and all processes approach this point. 10

Q3. (*a*) A centrifugal compressor compresses air at ambient temperature and pressure of 288 K and 1.01 bar respectively. The impeller tip speed is 364 m/s, the radial velocity at the exit from the impeller is 28 m/s, and the slip factor is 0.891. Calculate the Mach number of the flow at the impeller tip. If the impeller total-to-total efficiency is 0.881 and the flow area from the impeller is 0.085 m^2, calculate the mass flow rate of air. Assume an axial entrance at the impeller eye and radial blades. Take isentropic index of air as 1.4, specific heat at constant pressure as 1005 J/kg K. 20

(*b*) The incremental fuel costs for two generating units a and b of a power plant are given by the following relations:

$$\frac{dF_a}{dP_a} = 0.07P_a + 55$$

$$\frac{dF_b}{dP_b} = 0.08P_b + 50$$

where F is the fuel cost in rupees per hour and P is the power output in MW. Calculate,

(i) the economic loading of the two units when the total load supplied by the power plants is 500 MW.

(ii) the loss in fuel cost per hour if the load is equally shared by both the units. 10

(*c*) Air at 15°C and 1.03 bar occupies 0.02 m^3. The air is heated at constant volume until the pressure is 4.2 bar and then cooled at constant pressure to initial temperature 15°C. Calculate the net heat flow to or from the air and the net entropy change of air. Treat air as ideal gas. Take C_p of air as 1.005 kJ/kg K and C_v as 0.718 kJ/kg K. 10

Q4. (*a*) Determine the value of compressibility factor at critical point for gases following Van der Waal's equation of state. 15

(*b*) The power P developed by a water turbine depends on the rotational speed N, operating head H, gravity g, diameter D and breadth B of the runner, density ρ and viscosity μ of water. Show by using Buckingham's π-theorem method,

$$P = \rho D^5 N^5 \phi\left[\frac{H}{D}, \frac{D}{B}, \frac{\rho D^2 N}{\mu}, \frac{ND}{\sqrt{gH}}\right]$$ 15

(*c*) The following particulars refer to an experimental determination of the calorific value of a sample of fuel containing 88% C and 4.2% H_2. Mass of fuel is 0.848 gm. Mass of fuse wire 0.027 gm, of calorific value 6700 J/gm. Mass of water in the calorimeter is 1950 gm. Water equivalent of calorimeter is 380 gm. It is observed that rise in temperature is 3.06°C. The cooling correction is 0.017°C.

Find the higher calorific value of the fuel. Take C_p of water as 4.18kJ/kgK. 10

SECTION B

Q5. (*a*) Define (i) fin effectiveness ε_f, and (ii) fin efficiency η_f. Obtain expressions for ε_f and η_f for an infinitely long fin of uniform cross-section. Also, from the expression derived for ε_f, enumerate the conditions under which use of fins can be justified. 8

(*b*) Liquid nitrogen is stored in a thin walled spherical container of 100 cm diameter. The system is insulated by an evacuated space between the inner sphere and the surroundings with 105 cm concentric sphere. Both the spheres are made of aluminium and have an emittance of 0.03. The inner surface of the sphere is maintained at 77.4 K and the temperature of the outer sphere is 280 K. The latent heat of vaporization of nitrogen is 200 kJ/kg. Estimate

(i) the rate of heat flow by radiation to the nitrogen in the container, and

(ii) the nitrogen boil-off rate. 8

(*c*) A room is to be kept at a temperature of 20°C and a pressure of 1.013 bar. The moist air at 430 m^3/hr is drawn from a supply at 5°C, 1.013 bar and 70% relative humidity, and is saturated with water vapour in a sprayer. Determine the amount of water added per hour at 5°C. 8

Partial pressure of water vapour at 5°C = 0.0061 bar.

For air, R = 287 J/kJ K.

(*d*) Mention which factors affect the octane requirement of an engine. 8

(*e*) Draw the schematic representation of disintegration of fuel jet in CI engine without swirl and with swirl. 8

Q6. (*a*) A vapour compression refrigeration system of 2400 kJ/min capacity works at an evaporator temperature of –10°C and a condenser temperature of 50°C. The refrigerant R134a is subcooled by 5°C before entering the expansion valve and the vapour is superheated by 5°C before leaving the evaporator. The compression of the refrigerant is reversible adiabatic. The refrigeration compressor is having two cylinders, single acting with stroke equal to 1.5 times the bore and runs at 1000 rpm. Determine: (i) Refrigeration effect per kg of refrigerant, (ii) Mass of refrigerant circulated per minute, (hi) Theoretical piston displacement per minute, (iv) Power required to run the compressor, and (v) Bore by stroke of the compressor cylinder. Thermodynamic properties of R134a are attached. 15

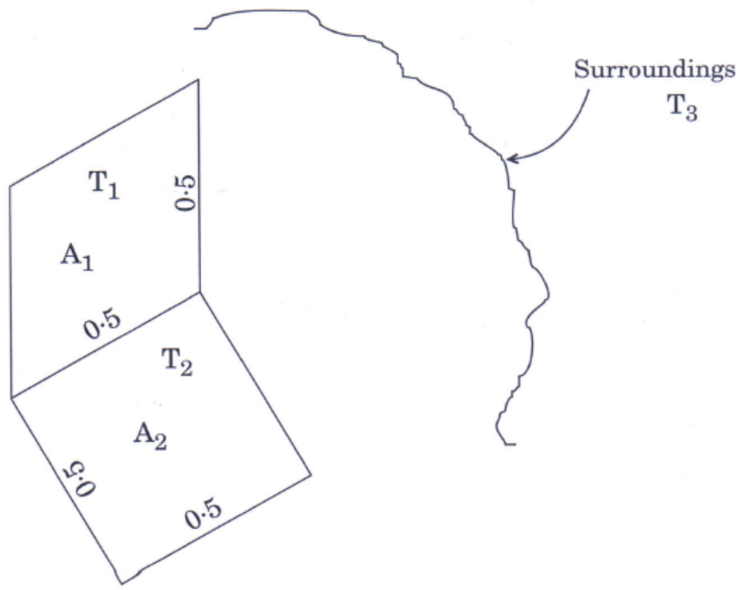
(*b*) A simple jet carburettor is required to supply 6 kg of air per minute and 0.45 kg of fuel of density 740 kg/m^3. The air is initially at 1.01325 bar and 27°C. Calculate the throat diameter of the choke for a flow velocity of 92 m/s. Velocity coefficient is 0.81.

If the pressure drop across the fuel metering orifice is 0.75 of that of the choke, calculate orifice diameter assuming coefficient of discharge is 0.6. Take for air specific heat at constant pressure as 1000 J/kg K and isentropic index as 1.4. 15

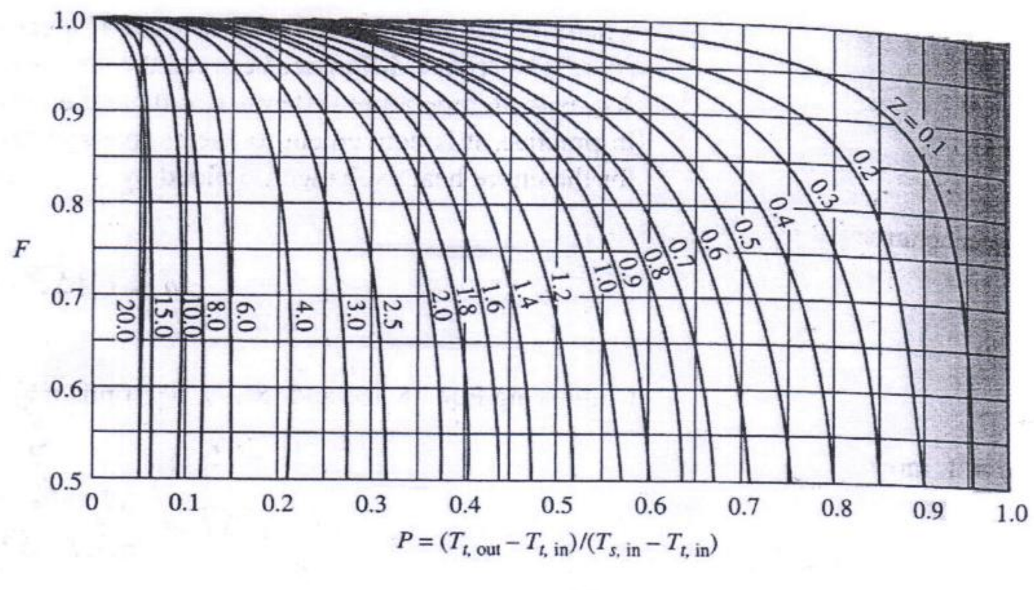
(*c*) Show that by Reynolds analogy for turbulent flow through a tube $St_d = f/8$

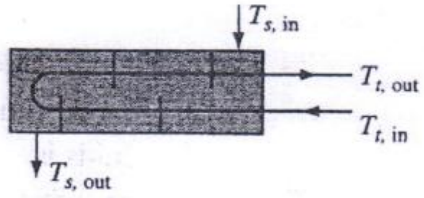
where f is the friction factor. 10

Q7. (*a*) Two square gray surfaces are oriented as shown in the figure. Surface A_1 is to be maintained at 400°C and surface A_2 at 800°C in a large surrounding whose walls are at 30°C. The surface properties are $t_1 = 0.5$ and $t_2 = 0.3$. Determine the energy supply requirements to maintain the surfaces at the given temperatures. Assume $F_{12} = F_{21} = 0.28$. Draw the equivalent network for radiation. 20



(*b*) Oil is used to heat water in a 1–2 heat exchanger (1 shell pass and 2 tube passes). Oil enters the tube at 240°C with a mass flow rate of 7 kg/sec. The heat exchanger is to be designed so that the water leaves the heat exchanger with a minimum temperature of 80°C. The flow rate of water is 10 kg/sec and it enters the heat exchanger at 20°C. Assuming an overall heat transfer coefficient of 525 W/m²K, determine heat transfer surface area required to achieve the outlet temperature of 80°C. Assume C_p of oil = 2.1 kJ/kg K. 10





Correction factor to counterflow LMTD for heat exchanger with one shell pass and two (or a multiple of two) tube passes.

(*c*) The following observations were made during a test on an oil engine: Brake power is 30 kW, fuel consumed is 10 kg/hr with calorific value of 42,000 kJ/kg. The mass flow rate of water circulated in water jacket is 9 kg/min. The rise in cooling water temperature is 60°C.
The exhaust gases are passed through an exhaust gas calorimeter for determining the heat carried away by exhaust gases. The calorimeter detail are as follows: water circulated through the calorimeter is 9-5 kg/min and the rise in temperature is 40°C. The exhaust gases leave the calorimeter at 80°C. Air/fuel ratio on mass basis is 20 and the ambient temperature is 17°C. Mean specific heat of exhaust gases is 1 kJ/kg K and specific heat of water is 4.18 kJ/kgK. Draw the heat balance on kJ/min and percentage basis. 10

Q8. (*a*) A spark ignition engine fuel has a composition of 86% carbon and 14% hydrogen by weight. The engine is supplied with a fuel having equivalence ratio of 1.20. Assume that all hydrogen is burnt and that the carbon burns to carbon monoxide and carbon dioxide so that there is no free carbon left. Calculate the percentage analysis of dry exhaust gases by volume. 15

(*b*) A bootstrap air refrigeration system is used for an aeroplane to take 10 TR load when it is flying at an altitude of 2000 m. The ambient air conditions are 0.8 bar and 15°C. The air is rammed isentropically from 0.8 bar to 1.05 bar. The pressure of air after isentropic compression in the main compressor is 3.5 bar and this is further compressed in a secondary compressor to a pressure of 4.5 bar. The isentropic efficiencies of both the compressors are 90% and that of cooling turbine is 85%. The effectiveness of both the heat exchangers is 0.6. If the cabin is to be maintained at 20°C and the pressure in the cabin is 0.9 bar, find
(i) Mass of air passing through the cabin
(ii) Power used for the refrigeration system
(iii) COP of the system
Draw a neat sketch of the system and show the processes on T-s diagram. Take C_p = 1 kJ/kg K. 15

(*c*) A horizontal cylinder of 50 cm length and 3 cm diameter is suspended in water at 20°C. Calculate the rate of heat transfer if the surface temperature of the cylinder is maintained at 55°C. Also, determine the rate of heat transfer if the same cylinder is kept horizontally in a bath of light oil at 55°C. 10

Use the following properties:

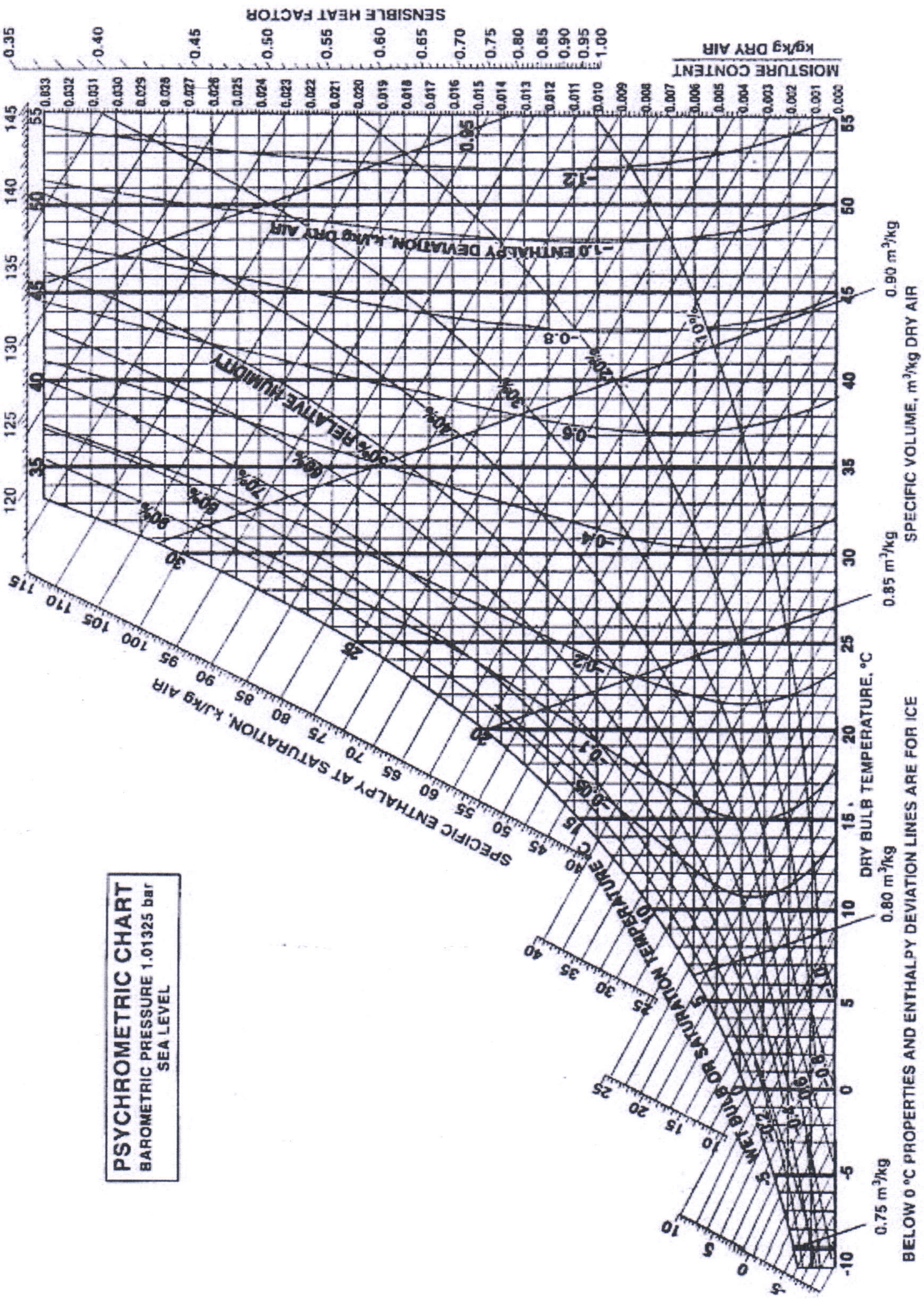
	Water	Oil
ρ (kg/m^3)	992	905
μ (kg/m hr)	2.47	82.0
k (W/mK)	0.622	0.133
β (K^{-1})	3.96×10^{-4}	7.2×10^{-4}
Pr	4.64	324

Use the following table:

R_{a_D}	C	n
$10^{-10} - 10^{-2}$	0.675	0.058
$10^{-2} - 10^{2}$	1.02	0.148

$10^2 - 10^4$	0.85	0.188
$10^4 - 10^7$	0.48	0.25
$10^7 - 10^{12}$	0.125	0.333

Ref. Point for S.H.F. is 25°C, 50% R.H.



THERMODYNAMIC PROPERTIES OF R134a*

Saturation table of R134a

Temp. °C	Pressure MPa	Density kg/m^3 Liquid	Volume m^3/kg Vapour	Enthalpy kJ/kg		Entropy kJ(kg. K)		Specific Heat c_p, kJ/(kg. K)		c_p/c_v Vapour
				Liquid	Vapour	Liquid	Vapour	Liquid	Vapour	
– 103.30[a]	0.00039	1591.1	35.4960	71.46	334.94	0.4126	1.9639	1.184	0.585	1.164
– 100.00	0.00056	1582.4	25.1930	75.36	336.85	0.4354	1.9456	1.184	0.593	1.162
– 90.00	0.00152	1555.8	9.7698	87.23	342.76	0.5020	1.8972	1.189	0.617	1.156
– 80.00	0.00367	1529.0	4.2682	99.16	348.83	0.5654	1.8580	1.198	0.642	1.151
– 70.00	0.00798	1501.9	2.0590	111.20	355.02	0.6262	1.8264	1.210	0.667	1.148
– 60.00	0.01591	1474.3	1.0790	123.36	361.31	0.6846	1.8010	1.223	0.692	1.146
– 50.00	0.02945	1446.3	0.60620	135.67	367.65	0.7410	1.7806	1.238	0.720	1.146
– 40.00	0.05121	1417.7	0.36108	148.14	374.00	0.7956	1.7643	1.255	0.749	1.148
– 30.00	0.08438	1388.4	0.22594	160.79	380.32	0.8486	1.7515	1.273	0.781	1.152
– 28.00	0.09270	1382.4	0.20680	163.34	381.57	0.8591	1.7492	1.277	0.788	1.153
– 26.07[b]	0.10133	1376.7	0.19018	165.81	382.78	0.8690	1.7472	1.281	0.794	1.154
– 26.00	0.10167	1376.5	0.18958	165.90	382.82	0.8694	1.7471	1.281	0.794	1.154
– 24.00	0.11130	1370.4	0.17407	168.47	384.07	0.8798	1.7451	1.285	0.801	1.155
– 22.00	0.12165	1364.4	0.16006	171.05	385.32	0.8900	1.7432	1.289	0.809	1.156
– 20.00	0.13273	1358.3	0.14739	173.64	386.55	0.9002	1.7413	1.293	0.816	1.158
– 18.00	0.14460	1352.1	0.13592	176.23	387.79	0.9104	1.7396	1.297	0.823	1.159
– 16.00	0.15728	1345.9	0.12551	178.83	389.02	0.9205	1.7379	1.302	0.831	1.161
– 14.00	0.17082	1339.7	0.11605	181.44	390.24	0.9306	1.7363	1.306	0.838	1.163
– 12.00	0.18524	1333.4	0.10744	184.07	391.46	0.9407	1.7348	1.311	0.846	1.165
– 10.00	0.20060	1327.1	0.09959	186.70	392.66	0.9506	1.7334	1.316	0.854	1.167
– 8.00	0.21693	1320.8	0.09242	189.34	393.87	0.9606	1.7320	1.320	0.863	1.169
– 6.00	0.23428	1314.3	0.08587	191.99	395.06	0.9705	1.7307	1.325	0.871	1.171
– 4.00	0.25268	1307.9	0.07987	194.65	396.25	0.9804	1.7294	1.330	0.880	1.174
– 2.00	0.27217	1301.4	0.07436	197.32	397.43	0.9902	1.7282	1.336	0.888	1.176
0.00	0.29280	1294.8	0.06931	200.00	398.60	1.0000	1.7271	1.341	0.897	1.179
2.00	0.31462	1288.1	0.06466	202.69	399.77	1.0098	1.7260	1.347	0.906	1.182
4.00	0.33766	1281.4	0.06039	205.40	400.92	1.0195	1.7250	1.352	0.916	1.185
6.00	0.36198	1274.7	0.05644	208.11	402.06	1.0292	1.7240	1.358	0.925	1.189
8.00	0.38761	1267.9	0.05280	210.84	403.20	1.0388	1.7230	1.364	0.935	1.192
10.00	0.41461	1261.0	0.04944	213.58	404.32	1.0485	1.7221	1.370	0.945	1.196
12.00	0.44301	1254.0	0.04633	216.33	405.43	1.0581	1.7212	1.377	0.956	1.200
14.00	0.47288	1246.9	0.04345	219.09	406.53	1.0677	1.7204	1.383	0.967	1.204
16.00	0.50425	1239.8	0.04078	221.87	407.61	1.0772	1.7196	1.390	0.978	1.209
18.00	0.53718	1232.6	0.03830	224.66	408.69	1.0867	1.7188	1.397	0.989	1.214
20.00	0.57171	1225.3	0.03600	227.47	409.75	1.0962	1.7180	1.405	1.001	1.219
22.00	0.60789	1218.0	0.03385	230.29	410.79	1.1057	1.7173	1.413	1.013	1.224
24.00	0.64578	1210.5	0.03186	233.12	411.82	1.1152	1.7166	1.421	1.025	1.230

(Contd.)

Temp. °C	Pressure MPa	Density kg/m^3 Liquid	Volume m^3/kg Vapour	Enthalpy kJ/kg		Entropy kJ(kg. K)		Specific Heat c_p, kJ/(kg. K)		c_p/c_v Vapour
				Liquid	Vapour	Liquid	Vapour	Liquid	Vapour	
26.00	0.68543	1202.9	0.03000	235.97	412.84	1.1246	1.7159	1.429	1.038	1.236
28.00	0.72688	1195.2	0.02826	238.84	413.84	1.1341	1.7152	1.437	1.052	1.243
30.00	0.77020	1187.5	0.02664	241.72	414.82	1.1435	1.7145	1.446	1.065	1.249
32.00	0.81543	1179.6	0.02513	244.62	415.78	1.1529	1.7138	1.456	1.080	1.257
34.00	0.86263	1171.6	0.02371	247.54	416.72	1.1623	1.7131	1.466	1.095	1.265
36.00	0.91185	1163.4	0.02238	250.48	417.65	1.1717	1.7124	1.476	1.111	1.273
38.00	0.96315	1155.1	0.02113	253.43	418.55	1.1811	1.7118	1.487	1.127	1.282
40.00	1.0166	1146.7	0.01997	256.41	419.43	1.1905	1.7111	1.498	1.145	1.292
42.00	1.0722	1138.2	0.01887	259.41	420.28	1.1999	1.7103	1.510	1.163	1.303
44.00	1.1301	1129.5	0.01784	262.43	421.11	1.2092	1.7096	1.523	1.182	1.314
46.00	1.1903	1120.6	0.01687	265.47	421.92	1.2186	1.7089	1.537	1.202	1.326
48.00	1.2529	1111.5	0.01595	268.53	422.69	1.2280	1.7081	1.551	1.223	1.339
50.00	1.3179	1102.3	0.01509	271.62	423.44	1.2375	1.7072	1.566	1.246	1.354
52.00	1.3854	1092.9	0.01428	274.74	424.15	1.2469	1.7064	1.582	1.270	1.369
54.00	1.4555	1083.2	0.01351	277.89	424.83	1.2563	1.7055	1.600	1.296	1.386
56.00	1.5282	1073.4	0.01278	281.06	425.47	1.2658	1.7045	1.618	1.324	1.405
58.00	1.6036	1063.2	0.01209	284.27	426.07	1.2753	1.7035	1.638	1.354	1.425
60.00	1.6818	1052.9	0.01144	287.50	426.63	1.2848	1.7024	1.660	1.387	1.448
62.00	1.7628	1042.2	0.01083	290.78	427.14	1.2944	1.7013	1.684	1.422	1.473
64.00	1.8467	1031.2	0.01024	294.09	427.61	1.3040	1.7000	1.710	1.461	1.501
66.00	1.9337	1020.0	0.00969	297.44	428.02	1.3137	1.6987	1.738	1.504	1.532
68.00	2.0237	1008.3	0.00916	300.84	428.36	1.3234	1.6972	1.769	1.552	1.567
70.00	2.1168	996.2	0.00865	304.28	428.65	1.3332	1.6956	1.804	1.605	1.607
72.00	2.2132	983.8	0.00817	307.78	428.86	1.3430	1.6939	1.843	1.665	1.653
74.00	2.3130	970.8	0.00771	311.33	429.00	1.3530	1.6920	1.887	1.734	1.705
76.00	2.4161	957.3	0.00727	314.94	429.04	1.3631	1.6899	1.938	1.812	1.766
78.00	2.5228	943.1	0.00685	318.63	428.98	1.3733	1.6876	1.996	1.904	1.838
80.00	2.6332	928.2	0.00645	322.39	428.81	1.3836	1.6850	2.065	2.012	1.924
85.00	2.9258	887.2	0.00550	332.22	427.76	1.4104	1.6771	2.306	2.397	2.232
90.00	3.2442	837.8	0.00461	342.93	425.42	1.4390	1.6662	2.756	3.121	2.820
95.00	3.5912	772.7	0.00374	355.25	420.67	1.4715	1.6492	3.938	5.020	4.369
100.00	3.9724	651.2	0.0268	373.30	407.68	1.5188	1.6109	17.59	25.35	20.81
101.06[c]	4.0593	511.9	0.00195	389.64	389.64	1.5621	1.5621	∞	∞	∞

[a]Triple point [b]NBP [c]Critical point

* Ashrae Handbook Fundamentals, 2005.