MECHANICAL ENGINEERING Paper I

Time Allowed: Three Hours **Maximum Marks: 200**

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 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.

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SECTION 'A'

1. Answer any four of the following (each answer should conform to a limit of around 150 words):

(a) (i) Distinguish between the laws of friction for dry and film lubricated surfaces. What conditions must be satisfied in order that film lubrication may be obtained.

(ii) Explain the difference between oiliness and viscosity of a lubricant. Discuss the conditions under which friction between two lubricated surfaces is influenced by the two properties respectively. 5 + 5

(b) Explain briefly the role of factors that influence, the change in the sum of tensions on the slack and tight side of a belt transmission, as power transmitted is increased. Why is a horizontal drive capable of transmitting more power than a similar vertical drive? 10

(c) Explain clearly the meanings of terms: elastic solid, non-elastic solid, inelastic solid; linearly elastic solid, and nonlinearly elastic solid. Illustrate your answer using a diagram showing the load deformation relationship for the above solids. 10

(d) (i) Define allotropy. Give an example of different allotropic forms of a material.

(ii) What is edge dislocation?

(iii) Prove that the atomic packing factor of a HCP (Hexagonally, Close-Packed) structure is 0.74. 3 + 3 + 4

(e) (i) What are solubility limits?

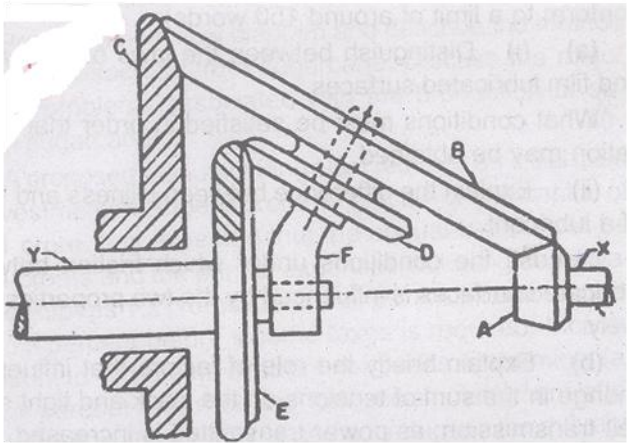
(ii) Describe an eutectic structure.

(iii) Why does the cooling curve for a pure metal show a isothermal hold at the freezing point? 3 + 3 + 4

2. (a) Explain briefly-why the static deflection curve of a loaded shaft may be used as a whirling form. Establish the relationship of critical speed with loads and load point deflections. 15

(b) A shaft Y is driven by a coaxial shaft X through the epicyclic gear train as shown in the figure. The wheel A is keyed to X, and E to Y. The compound wheel BD is carried on the arm F which can rotate freely about the common axis of X and Y. The wheel C is fixed.

The number of teeth on the gears A, B, C, D and E are respectively 20, 64, 80, 30 and 50. The shaft X rotates at 600 rpm clockwise looking from A. Determine the speed (in RPM) of Y and the direction of rotation, looking from E. 25



3. (a) A beam has a cross-section in the form of an isosceles triangle of base b and height h. Derive an expression for the magnitude of the maximum horizontal shearing stress under a vertical shear force V. What will be the location of the plane of this stress?

If the beam has b = 10 cm, and h = 30 cm find the magnitude of maximum shear stress, and the shear stress at neutral axis when V = 10,000 Kgf. 20

(b) Two springs, outside diameters 45 mm and 65 mm respectively are made with a steel wire of diameter 5 mm and are placed coaxially. Both the springs have 25 active coils but the outer spring is 27 mm longer than the inner one.

Find the compression of the inner spring when a load of 15 Kgf is placed on a plate supported initially by the outer spring. G for spring wire = 8×10^5 Kgf/cm^2. 20

4. (a) State the theories of failure based on the following criteria:

(i) Maximum Stress
(ii) Maximum Shear Stress
(iii) Maximum Strain Energy
(iv) Maximum distortion energy

Compare the safe stress domains based on the above criteria illustrating your answer with σ_1, σ_2; safe domain plot for a two dimensional stress state. Compare the safe values based on each of the above theories for the specific case $\sigma_1 = -\sigma_2$. 20

(b) Determine the width of 9.5 mm thick leather belt required to transmit 10 KW from a motor running at 750 rpm. The motor pulley is 300 mm diameter. The driven pulley runs at 250 rpm and the centre distance between the pulleys is 3 m. Assume an open belt drive with no slip and Relative Density of Leather = 1.0

Maximum Permissible Stress for leather belt = 2.46 N/mm^2.

Friction between belt and pulley = 0.3.

Neglect the sag of belt, and the effect of thickness of belt on velocity. 20

SECTION 'B'

5. Answer any four of the following (each answer should conform to a limit of around 150 words):

(a) (i) Explain the difference between tolerance and allowance.
(ii) Discuss the terms 'roughness' 'weaviness' and 'lay'. 4 + 6

(b) (i) Why is springback important in cold forming?
(ii) Why most press forging often employ heated dies?
(iii) What is 3-2-1 concept related to jig and fixture design? 3 + 3 + 4

(c) (i) What are various types of valve? What do you personally gain from valve engineering?
(ii) Give some examples of waiting time situations existing in industry. 5 + 5

(d) (i) Draw figure showing four waiting line structures.
(ii) What types of distributions are assumed for arrivals and services?

(iii) In a single channel waiting line if $\mu = \lambda$, what will be the utilization factor and mean waiting time for a customer before being served. μ = Av. no., of services provided per unit time and λ = Av. no. of arrivals per unit time. 3 + 3 + 4

(e) (i) Write the purpose of subroutine in a computer program including its general form.

(ii) Name three types of plotters used in computers to produce hard copy. 7 + 3

6. (a) (i) Write the circuits which make control loop unit (CLU) in CNC machine.

(ii) What is meant by the following codes?

g 9 0

m 0 3 10

(b) DC servomotor is coupled directly to a lead screw which drives the table of an NC machine tool. A digital encoder, which emits 500 pulses per revolution is mounted on the other end of the lead screw. If the lead screw pitch is 5 mm and motor rotates at 800 rpm calculate:

(i) The linear velocity of the table

(ii) The basic length unit (BLU) of the N.C. system

(iii) The frequency of the pulses transmitted by the encoder. 1 pulse = 1 BLU. 15

(c) (i) Explain with a figure stylus profile device for measuring surface roughness.

(ii) How Ra (arithmetic mean) value of surface roughness is defined. 15

7. (a) Florence Health INC is a Professional II nursing home aspiring to become Professional I nursing home. Administrator prepares the following list of activities:

Activity	Predecessor's Activity	Time estimates (Weeks)		
		t_0	t_m	t_P
B. Build facility	None	20	24	30
F. Safety Inspection	B	2	3	4
C. Install Equipment	B	8	16	20
D. Recruit Staff	None	2	2	3
E. Train Staff	D	4	5	6
A. Perform Pilot	C, E, F	6	5	9

Draw the PERT diagram and show the critical path (consider β-distribution). What is Time/Cost trade offs? 20

(b) Solve the assignment problem represented by the matrix given below: 20

	a	b	c	d	e	f
A	9	22	58	11	19	27
B	43	72	72	50	63	48
C	41	28	91	37	45	33
D	74	42	27	49	39	32
E	36	11	57	22	25	18
F	3	56	53	31	17	28

8. (a) (i) Discuss the principle and applications of slip gauges. What are the different grades of accuracy?

(ii) Draw Merchant's circular force diagram and write the assumptions. 20

(b) Solve the following linear programming problem:

Maximize $z = 3x_1 + 2x_2 + 5x_3$

Subject to $x_1 + 2x_2 + x_3 \leq 430$

$3x_1 + 2x_3 \leq 460$

$x_1 + x_2 \leq 420$

$x_1, x_2, x_3 \geq 0$. 20

MECHANICAL ENGINEERING Paper II

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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/cm^2 = 0.98 bar

1 bar = 10^5 pascals

Universal gas constant = 8314.6 J/kmol-K

Psychrometric chart is enclosed.

SECTION—A

1. Answer any four parts:

(a) (i) Two Carnot engines work in series between the source and sink temperatures of 600 K and 300 K. If both engines develop equal power, determine the intermediate temperature. 5

(ii) Show that the compression ratio for the maximum work to be done per kg of air in an Otto cycle between upper and lower limits of absolute temperatures T_3 and T_1 is given by the expression 5

$$r = \left(\frac{T_3}{T_1}\right)^{\frac{1}{2(\gamma+1)}}$$

(b) (i) An ideal gas is heated at constant volume until its temperature is 3 times the original temperature, then it is expanded isothermally till is reaches its original pressure, the gas is then restored to its original state. Determine the expression of net work done. 5

(ii) 300 kJ/sec of heat is supplied at a constant fixed temperature of 290 °C to a heat engine. The heat rejection takes place at 8.5 °C. The following results were obtained:

(i) 215 kJ/s of heat is rejected

(ii) 150 kJ/s of heat is rejected

(iii) 75 kJ/s of heat is rejected

Using Clausius inequality which of the results report a reversible cycle of irreversible cycle, or impossible result? 5

(c) (i) What is HUCR (highest useful compression ratio)? Explain the terms, Octane number and Cetane number. 5

(ii) What is petrol injection? What are its advantages and disadvantages? 5

(d) Make a detailed comparison of SI and CI engines with respect to basic cycle, fuel, introduction of fuel in the cylinder, ignition, compression ratio and weight. 10

(e) Two parallel flat plates of equal area 0.5 m^2 each face each other. These are at 1000 K and 500 K respectively. Shape factor between them $F_{12} = F_{21} = 0.285$. These are placed in room whose walls are at 300 K. Find radiation heat transfer rate between the plates and between the plates and wall. Assume that outer part of both the plates is insulated. Stefan-Boltzmann constant = 5.67×10^{-8} W/K^4-m^2. 10

2. (a) What is detonation? 'Factors leading to increase detonation in SI engines tend to reduce knock in CI engines. Discuss the validity of the two phenomena states above in the light of differences in their nature. Indicate the methods to reduce knock in CI engines. 20

(b) Determine the diameter of a fuel orifice for a 4-stroke engine working on diesel cycle developing 18 kW per cylinder at 2000 revolutions per minute, using 0.27 kg/kW-hr fuel of 30° API. The duration of the crank injection is 30° of crank travel. The fuel injection pressure is 125 bar and the combustion chamber pressure is 35 bar. Take velocity coefficient as 0.9 and

$$P = \frac{141.5}{131.5 + °API}$$ 20

3. (a) (i) What is stoichiometric air requirement and excess air factor?

(ii) What do you understand by higher calorific value and lower calorific value? Explain the methods to measure them. 15

(b) Determine, the air-fuel ratio at 6000 m altitude in a carburetor adjusted to give an air-fuel ratio of 15 : 1 at sea level where the air temperature is 300 K and pressure of 1.013 bar.

The temperature of air decreases with altitude and is given by the expression

$$t = t_s - 0.0065h$$

where h is altitude in meters and t_s is the temperature at sea level in °C.

The air pressure decreases with altitude as per the relation

$$h = 19220 \log_{10}(1.013/P)$$

where, p is in bar.

What remedies would you suggest to compensate for the decrease in air fuel ratio at high altitudes? Discuss them giving justification. 25

4. (a) Show that the governing equation for temperature distribution in a fin of uniform cross-section is given by

$$\frac{d^2\theta}{dx^2} - m^2\theta = 0$$

where, $\theta = T - T_1$ and $m^2 = hP/kA$.

Further, show that the solution for boundary conditions $\theta = \theta_0$ at $x = 0$ and $\theta = \theta_1$, at $x = L$ is

$$\theta = \frac{\theta_1 \sinh mx + \theta_0 \sinh m(L - x)}{\sinh mL}$$ 15

(b) Water flows in the tube and brine flows in the annulus of a double-tube heat exchanger. Water at the rate of 0.15 kg/s is cooled from 30°C to 20°C and temperature of brine increases from –15°C to –5°C. The inner and outer diameters of water-carrying tube are 25 mm and 30 mm respectively, and thermal conductivity of metal is 45 W/m-K. The convective heat transfer coefficients on the brine and water, side are 2700 and 2100 W/m²-K respectively. Find overall heat transfer coefficient and then the length of the heat exchanger for parallel flow and counter flow. Specific heat of water = 4.18 kJ/kg-K. 25

SECTION—B

5. Answer any four parts:

(a) The evaporator and condenser temperatures in a reverse Carnot refrigeration cycle of 1 TR capacity are 263 K and 313 K respectively. The outlet of compression is saturated vapour and inlet to turbine is saturated liquid. Find the mass flow rate, work done condenser heat rejection and COP. Properties of refrigerant at saturation in SI units are as follows: 10

t (K)	h_f	h_g	s_f	s_g
263	154.056	1450.22	0.82965	5.755
313	390.587	1490.42	1.64377	5.1558

(b) Air enters a cooling coil at 30 °C, 75% relative humidity. The apparatus dew point is 12 °C and bypass factor is 0.15. Find the temperature and humidity ratio at outlet of cooling coil, if mass flow rate of air is 10 kga/s, find the condensate rate and cooling capacity of cooling coil. The partial pressures of water vapour at 12 °C and 30 °C are 1.4017 and 4.2431 kPa respectively. Atmospheric pressure is 101.325 kPa. Enthalpy of condensate at 12 °C = 50.24 kJ/kg. 10

(c) Explain the nomenclature Rabc for CFCs and inorganic compounds. What is meant by ozone depletion? Name at least two refrigerants that do not cause it. 10

(d) State Buckingham's π theorem. Using Buckingham's π theorem obtain an expression for drag force on a partially submerged body moving with a relative velocity V in a fluid, the other variables being linear dimension L, height of surface roughness K, the fluid density ρ and gravitational acceleration g. 10

(e) Discuss the criteria for the selection of site for steam and hydroelectric power plants. 10

6. (a) A refrigeration system of 10 TR cooling capacity has condenser and evaporator temperatures of 45 °C and - 20 °C respectively. The vapour leaving the evaporator sub-cools the liquid leaving the condenser from 45 °C to 25 °C. Draw schematic diagram and T-S diagram considering isentropic compression, isobaric heat absorption and rejection. Determine mass flow rate, compressor work, condenser heat rejection and COP. Use vapour specific heat at condenser pressure to find adiabatic discharge temperature and enthalpy. The properties in SI units at saturation are: 25

	h_f	h_g	s_g	C_{pg}	C_{pf}
–20°C	17.8	178.7	0.7088	0.61	--
45°C	79.7	204.9	0.6812	0.755	1.02

(b) Define thermodynamic wet bulb temperature t* and show that humidity ratio may be expressed as

$$W = \frac{W^* h_{fg}^* - 1.005(t - t^*)}{h_g(t) - h_f^*}$$

where enthalpy of moist air is expressed as h = 1.005 (t) + h_g (t). 15

7. (a) Diabetic flow of dry air takes place through a frictionless constant area duct. At some particular section of the duct, the Mach number is 4.0 while stagnation temperature and static pressure are 280 K and 0.5 bar respectively. Calculate the stagnation temperature, static and stagnation pressures at a section where the Mach number is 2.0. Also find the amount of heat transfer which causes this reduction in Mach number, take C_P = 1.005 kJ/kg and γ = 1.4. 20

M	P/P*	T/T*	T_0/T_0^*	P_0/P_0^*
2.0	0.364	0.529	0.793	1.503
4.0	0.1026	0.168	0.589	8.227

(b) Explain what you understand by specific speed of a turbo machine. Give its importance.

Calculate the specific speeds of the following cases:

(i) A 2500 kW gas turbine is running at a speed of 18000 RPM. The entry and exit conditions of the gas are T_1 = 1100 K, P_1 = 60 bar, P_2 = 30 bar.

(ii) A centrifugal compressor develops a pressure ratio of 1.5 while running at 24000 RPM and discharging 2.0 kg/s of air. The entry conditions are P_1 = 1.0, T_1 = 290 K.

1 or both cases take γ = 1.4, R = 287 J/kg-K, C_P = 1.005 kJ/kg-K. 20

8. (a) Explain clearly, 'Heat rate curve' and 'Incremental rate curve'. Show that the incremental rate curve crosses the heat rate curve at the lowest value of heat rate.

The incremental fuel costs for two generating units A and B of a plant are given by

$$dF_a/dP_a = 0.065\ dP_a + 25$$
$$dF_b/dP_b = 0.065\ dP_b + 25$$

where F is fuel cost in Re/hr and P is power output in MW Find -

(i) the economic loading of the two units when the total load supplied by the power plant is 160 MW.

(ii) the loss in fuel cost/hr if the load is shared equally by the units. 25

(b) Discuss the importance of the terms, capacity factor and use factor from the economic point of view of the power plant. A power station is said to have a use factor of 50% and a capacity factor of 45%. How many hours the plant did not operate during the year? 15