MECHANICAL ENGINEERING Paper I

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

INSTRUCTIONS

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

Candidates should attempt **FIVE** *questions in all. Question No,* **1** *is compulsory.*
Out of the remaining **SIX** *questions attempt any* **FOUR** *questions.*
The number of marks carried by a part of a question are indicated against it.
Answers must be written in **ENGLISH** *only.*
Assume suitable data, if necessary, and indicate the same clearly.
For air R = 0.287 *kJ/kg-K,* C_p = 1.005 *kJ/kg-K,* γ = 1.4, M = 28.97 *kg/kg-mole, Universal gas constant* R = 8.314 *kJ/kg mole-K.*
Unless otherwise mentioned, symbols and notations have their usual standard meanings.
Neat sketches may be drawn, wherever required.
Attempts of questions shall be counted in chronological 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 answer book must be clearly struck off.
A psychrometric chart is attached to this question paper for necessary use by the candidate.

1. (a) Liquified Petroleum Gas (LPG) is sold in small cylinders for use as cooking gas. If one LPG cylinder contains 15 kg gas, express the quantity of gas contained in the cylinder in moles. Treat LPG as Butane (C_4H_{10}) only. 5

(b) A heat engine operates between a source at 550°C and a sink at 25°C. If the heat is supplied to the heat engine at a steady rate of 1200 kJ/min, determine the maximum power output of this heat engine in kW. 5

(c) Explain the effect of combustion chamber shape and location of spark plug on detonation in an S.I. engine. 5

(d) Specify the conventional and alternative refrigerants for the following applications:
(i) Domestic refrigerators and
(ii) Central Air-conditioning plants. 5

(e) Discuss the various factors affecting boundary layer thickness. 5

(f) If it is possible to describe a turbulent flow by the equation:

$$u - 5 + 0.5 \sin t,$$

then, calculate:
(i) $\overline{u'}$ and
(ii) $\left(\overline{u'^2}\right)^{1/2}$ 5

(g) Write expression for hydraulic efficiency of a water turbine. How does the efficiency vary with part load? 5

(h) Explain the terms slip and slip factor, as applied to centrifugal compressor. Write expressions for these terms. 5

2. (a) A spherical balloon of 1 m diameter contains a gas at 200 kPa and 300 K. The gas inside the balloon is heated until the pressure reaches 500 kPa. During the process of heating, the pressure is proportional to the diameter of the balloon. Determine the work done by the gas inside the balloon. 10

(b) A gas turbine engine with regeneration operates with two stages of compression and two stages of expansion. The pressure ratio across each stage of compressor and turbine is 3.5. The air enters each stage of the compressor at 300 K and each stage of the turbine at 1200 K. The compressor and turbine efficiencies are 78 and 86 percent, respectively. The effectiveness of the regenerator is 72 percent. Determine the back work ratio and the thermal efficiency of the cycle, assuming constant specific heats for air at room temperature. 20

(c) Derive expressions for Δu, Δh and Δs for a gas that obeys the van der Waals equation of state for an isothermal process. 10

3. (a) An ammonia ice plant operates between a condenser temperature of 35°C and an evaporator temperature of –15°C. It produces 10 tons of ice per day from water at 32°C to ice at –3°C. Assuming simple saturation cycle, determine:

(i) the capacity of the refrigeration plant.

(ii) the mass flow rate of refrigerant.

(iii) the compressor cylinder diameter and stroke if its volumetric efficiency is 70%, rpm = 1250 and stroke to bore ratio is = 1.3.

(iv) the power of the compressor motor if the adiabatic efficiency of the compressor = 0.86 and mechanical efficiency = 0.94.

(v) the theoretical and actual COP.

Assume latent heat of ice = 335 kJ/kg

Specific heat of water = 4.1868 kJ/kgK.

Specific heat of ice =1.94 kJ/kgK.

The properties of NH_3 are given below:

T	v_f	v_g	h_f	h_g	s_f	s_g
°C	$\times 10^3$ m³/kg	m³/kg	(kJ/kg)		(kJ/kg-K)	
–15	1.52	0.508	131.3	1443.9	0.7426	5.8223
35	1.7	0.096	366.1	1488.6	1.566	5.2086

Average specific heat of ammonia vapour is 2.2 kJ/kg-K. 20

(b) In an oil engine, working on dual combustion cycle the temperature and pressure at the beginning of compression are 90°C and 1 bar. The compression ratio is 13 : 1. The heat supplied per kg of air is 1675 kJ, half of which is supplied at constant volume and half at constant pressure. Calculate (i) the maximum pressure in the cycle, and (ii) the percentage of stroke at which cut-off occurs.

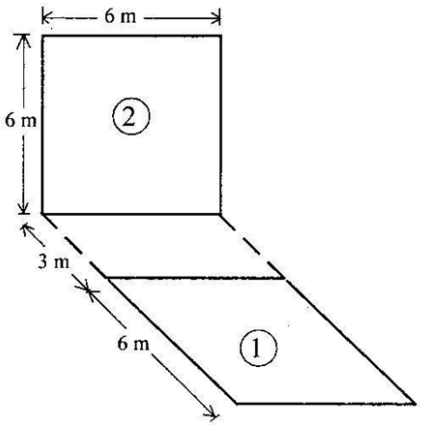
Take γ for compression 1.4, R = 0.287 kJ/kgK and C for products of combustion is $0.71 + 20 \times 10^{-5}$ T where T is in K. 10

(c) Explain using psychrometric chart, the process of mixing of two air streams with condensation. 10

4. (a) Consider a solid sphere of radius R, the surface of which is maintained at t_s. If the sphere has a uniform internal heat generation rate of q* per unit volume, derive expressions for the temperature distribution in the sphere and the temperature at the sphere center. Take the thermal conductivity to be constant. 15

(b) A heat exchanger tube with inner and outer diameters 2.118 cm and 2.54 cm respectively is equipped with 20 equally spaced straight fins of uniform thickness placed longitudinally along the tube. The fins are 2.5 cm long in the radial direction and are 0.16 cm thick. Both the tube and the fins are made of steel with k = 45 W/m°C. The inside and outside heat transfer coefficients are 1130 and 255 W/m²°C, respectively. What is the overall heat transfer coefficient for the exchanger based on the outer exposed surface area? Compare this result with that for the same tube without fins, subjected to the same heat transfer coefficients. 15

(c) Find the shape factor F1-2 for the configuration shown in the figure. 10



5. (a) Find the expression for the thrust F on the propeller of a ship. This thrust will be a function of mass density ρ and dynamic viscosity μ of the liquid and diameter d, speed of advance v and rotational speed n of the propeller. 15

(b) A smooth flat rectangular plate is placed edgewise in a stream of fluid. At what fraction of the length from the leading edge would the drag force on the front portion be equal to half of the total drag force? Assume the boundary layer to be laminar. 10

(c) Derive an expression for the work done per second by water on the runner of Pelton turbine. Prove that for a given jet speed, volume flow rate, turning angle and wheel radius the maximum efficiency occurs when the turbine bucket moves at half the jet speed. 15

6. (a) A pitot-static tube is inserted into an airstream of velocity U_0, pressure 1.02×10^5 Nm^{-2} and temperature 28°C. It is connected differentially to a mercury U-tube manometer. Calculate the difference of mercury levels in the two limbs of the manometer if the velocity U_0 is:
(i) 50 ms^{-1} and (ii) 420 ms^{-1}.
Take the specific gravity of mercury as 13.6 and for air $\gamma = 1.4$, R = 0.287 kJ/kg-K. 15

(b) It is required to convey 10 m^3/s of water at a mean velocity of 1.25 m/s. Calculate the dimensions of the most efficient section of the following:
(i) rectangular
(ii) triangular
(iii) trapezoidal and
(iv) circular.
Which of these has/have the least perimeter and the longest perimeter? 15

(c) Derive an expression for area velocity relationship for a compressible fluid in the form:

$$\frac{dA}{A} = \frac{dV}{V}\left(M^2 - 1\right)$$

Further, explain the variation of velocity with change in area for:
(i) subsonic velocity
(ii) sonic velocity and
(iii) supersonic velocity. 10

7. (a) An axial flow compressor has an overall pressure ratio of 4.0 and mass flow of 160 kg/min. If the polytropic efficiency is 0.88 and stagnation pressure rise per stage must not exceed 25°C, calculate the number of stages required and the pressure ratio of the first and last stage. Assume equal temperature rise in all stages. If the absolute velocity approaching the last rotor is 155 m/s at an angle of 20° from the axial direction, the work done factor is 0.83, the velocity diagram is symmetrical and the mean diameter of the last stage rotor is 180 mm, compute the rotational speed and the length of the last stage. Ambient conditions are 1.01 bar and 288 K. 25

(b) What are the essentials of a good steam boiler? Enumerate the factors which should be considered while selecting a boiler. 15

MECHANICAL ENGINEERING Paper II

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

INSTRUCTIONS

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

Candidate should attempt **FIVE** *questions in all. Question No.* **1** *in Section* **A** *is compulsory.*

Out of the remaining, attempt **TWO** *from Section-***B** *and* **TWO** *from Section—***C**.

All questions carry equal marks. The number of marks carried by a part of a question is indicated against it.

Answer must be written in **ENGLISH** *only.*

Unless other-wise mentioned, symbols and notations have their usual standard meanings.

Neat sketches may be drawn, wherever required.

All parts and sub-parts of a question are to be attempted together in the answer book.

Attempts of questions shall be counted in chronological 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 answer book must be clearly struck off.

SECTION—A

1. Answer all the 10 (ten) parts of the Question No. 1. (Each part carries 4 marks)

(a) With the help of a free-body diagram, derive an expression for the effort P applied at the circumference of the screw to lift the load W. The coefficient of friction is μ and the helix angle is α.

(b) Sketch and explain the working of centrifugal clutch. Give one application of it.

(c) A thin cylindrical shell with hemispherical ends is subjected to internal fluid pressure. For equal maximum stress to occur in both the cylindrical and the spherical portions, what would, be the ratio of thicknesses of the spherical portion to that of the cylindrical portion?

(d) Two close coiled helical springs A and B made of the same wire show axial compressions of 8 mm and 3 mm, respectively, when they are subjected to the same axial load. The spring A has 9 coils of mean diameter of 80 mm, while the spring B has 8 coils. Determine the mean coil diameter of the spring B.

(e) Explain the purpose of process annealing. How it is done? Discuss in short about bainite.

(f) Name four materials used as shaped tool in electrochemical machining. What types of materials are normally cut using high-pressure inert gas-assisted laser and why?

(g) Write the reasons which result the metals to shrink during solidification and cooling in metal casting. What are hot tears and cold shut?

(h) Explain the terms comminution and reduction used in powder metallurgy. Why lubricants are used to mix the metal powders?

(i) Name 4 basic ways of establishing a time standard.

(j) Consider the following formulas for statistics problems:

$$\text{Mean} = \mu = \frac{1}{N}\sum_{i=1}^{N} d_i$$

$$\text{Standard deviation} = \sqrt{\sigma}$$

$$\text{Variance} = \sigma^2 = \frac{1}{N}\sum_{i=1}^{N}(d_i - \mu)^2$$

Write a C coding for the above.

SECTION—B

2. (a) At a point in a loaded component the state of stress is given by σ_x = 270 MPa, σ_y = 130 MPa and $\tau_{xy} = \pm$ 40 MPa.

Determine

(i) the maximum and minimum principal stresses and the planes on which they act.

(ii) the maximum shearing stress in magnitude and direction. 10

(b) One of the turning pairs of a four-bar chain is replaced by a sliding pair. Draw the inversions by fixing different links. Give one application for each of the mechanism. 10

(c) A 100 mm steel drive shaft transmitting 150 kW at 300 r.p.m. has to be connected to a machine having same diameter shaft with a cast iron (CI) unprotected flange coupling. The permissible shear stress for the shaft, bolt and key are 50 MPa. The bearing stress for bolt and key are 50 MPa and shear stress for CI is 8 MPa. The basic dimensions of the coupling may be assumed as per the standard. Design the coupling and verify all the major dimensions for strength. 20

3. (a) A steel beam of rectangular section has a span of 8 m and is simply supported at its ends. It is required to carry a total load of 60 kN uniformly distributed over the whole span. Find the minimum values of breadth and depth if the maximum bending stress is not to exceed 50 MPa, and the maximum deflection is limited to 10 mm. E = 210 GPa. 10

(b) (i) State the law of gearing to maintain the condition for constant velocity ratio between a pair of toothed wheels. Name two types of gear tooth profiles to satisfy these. 5

(ii) A pinion having 36 teeth drives a gear having 96 teeth. The profiles of the gears are involute with 20° pressure angle, 10 mm module and 10 mm addendum. Find the length of path of contact, arc of contact and contact ratio. 5

(c) In rotor system, three unbalanced masses m_1 = 1.2 kg, m_2 = 1.8 kg and m_3 = 2.4 kg. The radius and angular positions of these masses from the horizontal plane are: R_1 = 1.135 m at 113.4°, R_2 = 0.822 m at 48.8° and R_3 = 1.04 m at 251.4°. Two balancing masses of m_A and m_B are on left and right ends of the rotor respectively. The distances of unbalanced masses and right side balance mass from the left end unbalance mass m_A are l_1 = 0.854 m, l_2 = 1.701 m, l_3 = 2.396 m and l_B = 3.097 m. Find the mass-radius product and angular locations of balancing masses m_A and m_B for dynamic balance of the rotor system. 20

4. (a) A hollow steel shaft 60 mm internal and 100 mm external diameter is to be replaced by a solid alloy shaft. If the polar modulus has the same value for both, calculate the diameter of the latter and the ratio of their torsional rigidities. Shear modulus G for steel = 2 times the G for the alloy. 10

(b) A vibrating system is characterised by the following parameters:
mass = m = 6 kg
stiffness of spring = k = 200 N/m
damping coefficient of the dashpot = c = 6 N-s/m
Determine
(i) the damping factor
(ii) the natural frequency of damped vibration
(iii) the number of cycles after which the original amplitude is reduced to 20 percent. 10

(c) A full journal bearing has a journal diameter D of 25 mm, with a unilateral tolerance of – 0.038 mm. The bushing bore has a diameter B of 25.038 mm and a unilateral tolerance of 0.075 mm. The l/D ratio is unity. The load is 1.1 kN and the journal runs at 18.33 r.p.s. The average viscosity is 55.2 mPa-s. Minimum film thickness variable is 0.58 and coefficient of friction variable is 4.0. Find
(a) Sommerfeld number
(b) minimum film thickness
(c) frictional torque. 10

(d) (i) Why are fee metals generally weak and ductile? Write the effects of adding chromium, nickel and molybdenum in steel. 5

(ii) Why plasticizers and lubricants are added to plastics? Name some important properties and applications of (a) nylon and (b) vinyls. 5

SECTION—C

5. (a) (i) Write the advantages, applications, current and power input that may be required in flash welding. Why flashing is essential? 5

(ii) In metal casting write the purpose and types of muller. Why distortion allowance is provided on patterns? 5

(b) (i) Name at least four methods by which high energy release rates are obtained. Why might less springback be observed in HERF? 5

(ii) Write at least four factors on which the thrust force in drilling depends.
A hole is being drilled on a block aluminum alloy with 10 mm drill at a feed of 0.25 mm/rev. The spindle is running at N = 850 r.p.m. Calculate the metal removal rate. 5

(c) (i) Why does titanium have poor machinability? Write at least four general characteristics that coatings for cutting tools and dies should possess. You are asked to turn ductile cast iron with various microstructure and hardness as shown in the following table.

		Hardness (HB)	Ferrite	Pearlite
1.	Annealed	186	91	3
2.	As cast	265	20%	80%
3.	Annealed	170	100	—
4.	As cast	207	60	40

Draw a figure showing variation of tool life with cutting speed and the effect of workpiece hardness and microstructure. 10

(ii) Schematically illustrate closed loop control system for a numerical control machine, mentioning the purpose of a feedback control. Write the advantages of CNC over conventional NC systems. 10

6. (a) (i) Define the terms accuracy and precision.
Name five main areas into which the measurement can be divided. Write the amount of allowance and tolerance that is permitted by the following classes of fit as per ANSI class 4: Snug fit and class 7: Medium force fit. Also mention applications. 5

(ii) Write two advantages of thread rolling and explain with figure two-die cylindrical machine. 5

(b) (i) Milling is an interrupted cutting process, show with figure conventional face milling with cutting force diagram for Fe showing the above nature of the process. 5

(ii) Name the basic components of all robots. Write in short about welding robot. 5

(c) The demand for a certain raw material used in a manufacturing organization varies from month to month. The consumption pattern of the material during the last six months (in metric tons) is given below:

Table: Consumption pattern of raw material (metric tons)

Month	Demand
Month 1	20
Month 2	30
Month 3	20
Month 4	40
Month 5	50
Month 6	60

(i) Using the method of moving averages, forecast the demand for month 7 using three period moving average. 5

(ii) Suppose the three periods have the weights of 0.50 for the immediate past and 0.25 for two and three periods before, what will be the new forecast? 5

(iii) Changing the number of periods for moving average to 2, 4 and 5, obtain the forecast in each of these cases. 5

(iv) What do you conclude from the results obtained in (i), (ii) and (iii)? 5

7. (a) A die making unit is planning to install a new CNC electric discharge machine in its job shop. Machines from two reputed manufacturers are available in the market.

The relevant data about their products is as under:

	Manufacturer A	Manufacturer B
Present cost	Rs. 1.00 cr	Rs. 1.50 cr
Annual operating + main tenance cost	Rs. 0.20 cr	Rs. 0.120 cr
Salvage value at the end of useful life	Rs. 0.05 cr	Rs. 0.02 cr
Estimated useful life	10 yrs	10 yrs

Considering rate of return to be 12% per year, what is the best alternative?

(P_{wf} -series at 12% for 10 yrs = 5.65; P_{wf} single payment at 12% for 10 yrs = 0.322) 10

(b) A manufacturer operates three factories from which items are shipped to four warehouses. Factory to warehouse shipping cost in Rs., quantities available at each of the factories X, Y and Z and requirements at each of the warehouses A, B, C and D are given in the table below:

Factory	Warehouses				Quantity
	A	B	C	D	available
X	30	20	50	20	150
Y	20	10	40	40	240
Z	20	30	40 .	30	210
Quantity required	130	120	160	190	600

Determine initial feasible solution by

(i) North-west corner rule, and

(ii) lowest cost entry method. 10

(c) A dual-card Kanban system needs to be designed for a manufacturing process that has a demand rate of 200 per hour of a certain item. The standard containers designed, for the components can hold 25 items. The conveyance time and production time for the components are 30 minutes and one hour, respectively. Assume a safety factor of 10%.

(i) identity the number of C-Kanbans and P-Kanbans required in the system.

(ii) if there is a rounding off involved in arriving at the number of Kanbans in the above case, compare the performance of the system when the number is rounded off to the immediate lower and next higher integer. 20