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) The heat capacity at constant pressure of a certain system is a function of temperature only and may be expressed as

$$C_p = 2.093 + \frac{41.87}{t+100} \text{ J/°C}$$

where t is the temperature in °C. The system is heated while it is maintained at a pressure of 1atmosphere until its volume increases from 2000 cm^3 to 2400 cm^3 and its temperature increases from 0°C to 100°C.

(i) Find the magnitude of heat interaction.

(ii) How much does the internal energy of the system increase? 5+5 = 10

(b) Derive the equations:

(i) $C_p = T\left(\frac{\partial V}{\partial T}\right)_p \left(\frac{\partial P}{\partial T}\right)_s$

(ii) $\left(\frac{\partial P}{\partial T}\right)_s = \frac{C_p}{V\beta T}$

(iii) $\frac{(\partial P/\partial T)_s}{(\partial P/\partial T)_V} = \frac{\gamma}{\gamma - 1}$ 10

(c) Show that for an ideal gas, the slope of the constant volume line on the T-s diagram is more than that of the constant pressure line. 5

(d) Explain the phenomenon of boundary layer separation. Describe four methods of controlling of boundary layer separation. 4 + 6 = 10

2. (a) Derive an expression for air/fuel ratio of a carburetor by

(i) Neglecting compressibility of air

(ii) Taking compressibility effects into account. 8 + 7 = 15

(b) A four stroke diesel engine of 3000 cc capacity develops 14 kW per m^3 of free air induced per minute. When running at 3500 rev/min it has a volumetric efficiency of 85 per cent referred to free air-conditions of 1.013 bar and 27°C. It is proposed to boost the power of the engine by supercharging by a blower (driven mechanically from the engine) of pressure ratio 1.7 and isentropic efficiency of 80 per cent. Assuming that at the end of induction the cylinders contain a volume of charge equal to the swept volume, at the pressure and temperature of the delivery from the blower, estimate the increase in bp to be expected from the engine. Take overall mechanical efficiency as 80 per cent, r for air = 1 4, R = 0.287 kJ/kg K. 13

(c) A liquid fuel C_7H_{16} is burned with 10% more air than the stoichiometric air. Assuming complete combustion, calculate

(i) the mass of air supplied per kg of fuel and
(ii) the volumetric analysis of the dry products of combustion, Assume air contains 21 per cent O_2 by volume. 12

3. (a) In a refrigeration system brine solution having a viscosity 16.5 N-s/m^2 and thermal conductivity 0.85 W/mk is flowing through a long pipe 2.5 cm inner diameter at a velocity of 6.1 m/s. Under these conditions the heat transfer coefficient was found to be 1135 W/m^2k for a brine temperature of –1°C and pipe temperature of 18.3°C. Find the temperature rise of brine per metre length of pipe if the velocity is doubled and same heat transfer takes place. Assume sp. heat of brine is 3768 J/kg K and density is 1000 kg/m^3. Assume fully developed flow. 8

(b) A solid sphere of diameter 10 cm is heated to 1000°C and suspended in a room whose walls are at 30°C. Compute the following:
(i) Rate of heat transfer due to radiation only neglecting other losses.
(ii) Time taken by the sphere to cool to 500°C assuming emissivity for the sphere = 0.1 and density 8.68 gm/cc. Sp. heat 0.098 J/kg K. 8

(c) Find the surface area required for a surface condenser dealing with 25000 kg of saturated steam per hour ata pressure of 0 5 bar. Temperature of condensing water is 25°C. Cooling water is heated from 15°C to25°C while passing through the condenser. Assume a heat transfer coefficient of 10 kW/m^2k. The condenser has 2 water passes with tubes of 19 mm OD and 1.2mm thickness. Find the length and no. of tubes per pass. Assume velocity of water is 1 m/s. Assume correction factor for 2 tube pass exchanger as 0.86. At 0.5 bar saturation temperature is 32.55°C and latent heat is 2560 kJ/kg. Sp. heat of water is 4.18 kJ/kg K and density is 1000 kg/m^3. 14

(d) Estimate the coefficient of heat transfer from a vertical plate 2 m × 2 m to the surrounding air at 25°C. The plate surface temperature is 150°C. Also calculate the rate of heat transfer from the plate. For air assume the kinematic viscosity as 1.6×10^{-5} m^2/s. The properties of air at film temperature are density 0.972 kg/ m^3, sp. heat 1.009 kJ/kg K, thermal conductivity 3.13×10^{-2} W/mK, Prandtl No. 0.69. The constants 'C & 'n' in Nusselt no. equation are 0.15 & 1/3 respectively. 10

4. (a) What factors are considered in selecting a refrigerant for the following application, mentioning the name of the refrigerant in each case
(i) Household refrigerator
(ii) An ice plant
(iii) Air conditioning plant for a cinema hall. 9

(b) A dense air refrigeration machine operating on Bell-Coleman cycle operates between 3.4 bar and 17 bar. The temperature of air after the cooler is 15°C and after the refrigerator is 6°C. If the refrigeration capacity is 6tons, calculate:
(i) temperature after compression and expansion
(ii) air circulation per min
(iii) work of compressor and expander
(iv) theoretical COP'
(v) rate of water circulation required in the cooler in kg/min if the rise in temperature is limited to 30°C. 10

(c) A simple saturation cycle using R12 is designed for taking a load of 10 tons. The refrigerant and ambient temperatures are 0°C and 30°C respectively. A minimum temperature difference of 5°C is required in evaporator and condenser for heat transfer. Find the
(i) mass flow rate through the system
(ii) power required in kW
(iii) cylinder dimensions assuming L/D ratio of 1.2 for a single cylinder single acting compressor if it runs at 300 rpm with a volumetric v of 0 9.
The following properties are taken for R12. Sp. heat of R12 vap = 0.95 kJ/kg K.

Sat. temp	Sat. pr	Sp. vol.		Enthalpy		Entropy	
		Sat. liq	Sat. vap	Sat. liq	Sat. vap	Sat. liq	Sat. vap
°C	bar	$\times 10^{-3}$ m³/kg		kJ/kg		kJ/kg K	
–5°C	2.61	0.71	0.0650	31.4	185.4	0.1251	0.6991
0°C	3.08	0.72	0.0554	36.1	187.5	0.1420	0.6966
30°C	7.45	0.77	0.0235	64.6	199.6	0.2399	0.6854
35°C	8.47	0.79	0.0206	69.5	201.5	0.2559	0.6839

10

(d) (i) What are the factors affecting comfort air conditioning? 3

(ii) Explain the air conditioning system used in winter season. 3

(iii) Show how air washer can be used for year round air conditioning? 3

(iv) A spray cooling coil is used to operate under the following conditions –
Air inlet 28°DBT, 21°WBT, Air outlet 10°DBT, 6°WBT. Total air flow rate 2000 m³/mt. Chilled water inlet and outlet temperatures are 7°C and 12°C. Find
(a) Cooling load on the coil
(b) Water flow rate through the coil.
Properties of moist air from psychometric chart are as follows: 2

DBT	WBT	Sp. humidity	Sp. vol.	Enthalpy
		gm/kg	m³/kg	kJ/kg
28	21.0	12.95	0.87	61.0
10	6.0	4.2	0.81	21.0

5. (a) (i) Explain what do you mean by Reynold's model law. Give two examples where Reynold's model can be applied.

(ii) An oil of specific gravity 0.92 and viscosity 0.03 poise is to be transported at the rate of 2500 L/S cm diameter pipe using water at 20°C. Determine,
1. Velocity of flow in the model
2. Rate of flow in the model
Given viscosity of water at 20°C is 0.01 poise. 3+2+4+2=11

(b) A rough pipe of diameter 0.1 m carries water at 20°Cat the rate of 50 L/S. If the average height of the roughness projections on the pipe surface is 0.15 mm, determine the
(i) friction factor
(ii) shear stress at the pipe surface
(iii) shear velocity
(iv) maximum velocity
Take for water at 20°C,
γ = Kinematic viscosity = 1×10^{-6} m²/s.
ρ = Mass density = 1000 kg/m³ 4 + 2 + 2 + 4 = 12

(c) Explain with the help of diagrams the phenomenon of Karman Vortex Street. How is Strouhal number, a dimensionless number, related to the above phenomenon? 5 + 3 = 8

(d) (i) Explain what do you mean by Temporal on Local acceleration, and convective acceleration.

(ii) The velocity field in a fluid medium is given by
$$V = 3xy^2i + 2xy\,j + (2zy + 3t)k$$
determine, the rotational velocity vector at (1, 2, 1) and t = 3. 2+2+5=9

6. (a) The velocity profile for a laminar boundary layer is given by
$$\frac{u}{U} = \sin\left(\frac{\pi}{2}.\frac{y}{\delta}\right)$$
where u is the velocity at a distance y from the plate U is the free stream velocity δ is the boundary layer thickness, determine expressions in terms of Reynold's number for the following:
(i) boundary layer thickness
(ii) drag force on both sides of the plate

(iii) co-efficient of drag. 15

(b) A Pitot-Static tube is used to monitor the velocity of an air stream. At the location of insertion of the probe, the static pressure is 1.5 bar and temperature is 35°C. Calculate the reading of a mercury manometer connected differentially across the static and total pressure openings of the probe, if the air stream velocity is
(i) 60 m/s (ii) 200 m/s (iii) 500 m/s.
Take into consideration the compressibility characteristics of the flow wherever applicable. The following values may be used
Isentropic table for perfect gas, k = 1.4

M	P/P_0
0.54	0.820
0.56	0.808
0.58	0.796
0.70	0.720
0.72	0.708
0.74	0.695

Normal shock table for perfect gas, k = 1.4

M_x	My	P_y/P_x	ρ_y/ρ_x
1.38	0.748	2.055	1.655
1.40	0.739	2.120	1.689
1.42	0.731	2.185	1.724
1.44	0.723	2.252	1.759

3 + 5 + 7 = 15

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

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

Explain properly, with the help of diagrams, what are the important conclusions derived from the above relationship. 4 + 6 = 10

7. (a) A three jet Pelton turbine is required to generate 10000 kW under a net head of 400 m. The blade angle at the outlet is 15° and the decrease in the relative velocity while passing over the blade is 5%. Determine,
(i) The diameter of the jet
(ii) The force exerted by a jet on the buckets.
Given, overall efficiency of turbine = 80%; co-efficient of velocity = 0.98; speed ratio = 0.46.
Further, if the jet ratio is not to be less than 10, calculate
(iii) speed of the wheel for a frequency of 50 hertz/sec.
(iv) corresponding wheel diameter. 16

(b) A centrifugal pump is to deliver 4.5 m^3/s when running at 750 rpm. The diameter of the impeller at inlet is 53 cm and at outlet is 76 cm. It may be assumed that the air enters radially with a speed of 15 m/s. The vanes are set backwards at outlet at 70° to the tangent, and width at outlet is 10 cm. The volute casing gives at 30% recovery of the outlet velocity head. The losses in the impeller may be taken as equivalent to 25% of the outlet velocity head. Blade thickness effects may be neglected. Determine,
(i) The manometric efficiency and
(ii) The pressure at the discharge. 16

(c) Discuss how the volumetric efficiency varies with the clearance and the pressure ratio in an air compressor. 8

8. (a) With the help of a neat Schematic explain the working of a Bubbling type Fluidized Bed Boiler. What are its advantages? 10

(b) A centrifugal compressor running at 16000 rpm takes in air at 17°C and compresses it through a pressure ratio of 4 with an isentropic efficiency of 82

per cent. The blades are radially inclined and the slip factor is 0.85. Guide vanes at inlet give the air an angle of pre-whirl of 20° to the axial direction. The mean diameter of the impeller eye is 200 mm and the absolute air velocity at inlet is 120 m/s. Calculate the impeller tip diameter. 15

(c) Explain briefly stage efficiency, internal efficiency and Reheat factor in a multistage steam turbine. Find out the relation between these three factors. 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 20 parts of the question each part carries 2 marks.

(a) A balance mass of value 2/3 m is placed diametrically opposite to the crank at crank radius r. What is the expression for the unbalanced force along the line of stroke of a reciprocating engine for angular position θ of the crank with respect to the line of stroke?

(b) (i) What is an isochronous governor?
(ii) State the phenomenon of hunting in a spring controlled governor.

(c) (i) Explain briefly vibration isolation and transmissibility.
(ii) The natural frequency of a system put on a foundation is ω_n. The operating frequency is ω. What is minimum value of (ω/ω_n) beyond which the vibration isolation is possible or meaningful?

(d) The Mohr's circle for a plane stress is a circle of radius R with its origin at +2R on σ axis. Sketch the Mohr's circle and determine σ_{max}, σ_{min}, σ_{av}, $(\tau_{xy})_{max}$ for this situation.

(e) Briefly explain the role of idle gears in a simple gear train, with the help of neat sketches.

(f) List two temporary fasteners and explain the working of one of these.

(g) The state of stress at a point in a loaded machine member is given by the principal stresses.

$$\sigma_1 = 600 \text{ MPa}, \sigma_2 = 0 \text{ and } \sigma_3 = -600 \text{ MPa}.$$

(i) What is the magnitude of the maximum shear stress?
(ii) What is the inclination of the plane on which the maximum shear stress acts with respect to the plane on which the maximum principal stress σ_1 acts?

(h) Two long columns are made of identical lengths '*l*' and flexural rigidities 'EI'. Column 1 is hinged at both ends whereas for column 2 one end is fixed and the other end is free.
(i) Write the expression for Euler's buckling load for column 1.
(ii) What is the ratio of Euler's buckling load of column 1 to that of column 2?

(i) A close coiled helical spring made of wire diameter d has mean coil radius R, number of turns n and modulus of rigidity G. The spring is subjected to an axial compression W.
(1) Write the expression for the stiffness of the spring.
(2) What is the magnitude of the maximum shear stress induced in the spring wire neglecting the curvature effect?

(j) List the conditions under which a rope drive is preferred to a belt drive.

(k) What is achieved by using a metallic single crystal casting? Give one application of a single crystal casting made of wasp alloy.

(l) In investment casting process two types of ceramics lurries are used. Why do we use them and in what sequence are they applied?

(m) What is the shape of a runner for making a sand mould? On what considerations is this shape selected?

(n) What does the following marking on a grinding wheel denote?

55-C-36-D-9-S-28

(o) Show crater wear and flank wear on a single point cutting tool. State the factors responsible for wear on a turning tool.

(p) Compare the drilling and boring operations in relation to cutting action, accuracy and applications.

(q) What is the effect on order quantity when the demand increases by four-fold in basic order point inventory system and other factors remain unchanged? Explain.

(r) A company is faced with a situation where it can either produce some item by adding additional infrastructure which will cost them Rs. 15,00,000/- but unit cost of production will be Rs. 5/- each. Alternatively it can buy the same item from a vendor at a rate of Rs. 20/- each. When should the company add to its capacity in terms of demand of items per annum? Draw the diagram to show the BEP.

(s) Define the term 'standard time' and list the common allowances given in work standard.

(t) Pointers are commonly used in 'C for creating linked lists. Write a FORTRAN code to implement pointers, that is, to traverse the linked list.

SECTION—B

2. (a) A cantilever of circular solid cross-section is fixed at one end and carries a concentrated load P at the free end. The diameter at the free end is 200 mm and increases uniformly to 400 mm at the fixed end over a length of 2 m. At what distance from the free end will the bending stresses in the cantilever be maximum?
Also calculate the value of the maximum bending stress if the concentrated load P = 30 kN. 15

(b) In a torsion test, the specimen is a hollow shaft with 50 mm external and 30 mm internal diameter. An applied torque of 1.6 kN-m is found to produce an angular twist of 0.4° measured on a length of 0.2 m of the shaft. The Young's modulus of elasticity obtained from a tensile test has been found to be 200 GPa. Find the values of
(i) Modulus of rigidity,
(ii) Poisson's ratio. 10

(c) A cylindrical shell has the following dimensions:
Length = 3 m
Inside diameter = 1 m
Thickness of metal = 10 mm
Internal pressure = 1.5 MPa
Calculate the change in dimensions of the shell and the maximum intensity of shear stress induced. Take E= 200 GPa and Poisson's ratio = μ = 0.3. 15

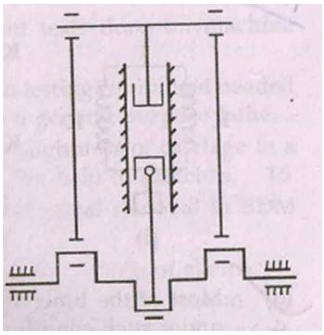
3. (a) (i) Explain the term 'Interference' in involute gears and how this can be avoided. 2

(ii) Derive the expression for minimum number of teeth on a pinion for Involute Rack to avoid interference. 8

(iii) Find the minimum number of teeth on the pinion to avoid interference when the addendum for stub teeth is 0.84 module and the pressure angle $\varphi = \cos^{-1}10.95$, if (a) the gear ratio is 3 to 1 and (b)the pinion meshes with a rack. 10

(b) A vertical single cylinder is shown in Figure 3(b). The lower piston is connected to the centre crank. The stroke is 80 mm for the lower piston. The upper piston

operates the two outer cranks which are at 180° to the centre crank. The reciprocating parts for the lower piston weigh 10kg. The reciprocating parts for the upper piston weigh 20 kg. Find the stroke of the upper piston when the primary force is balanced.



20

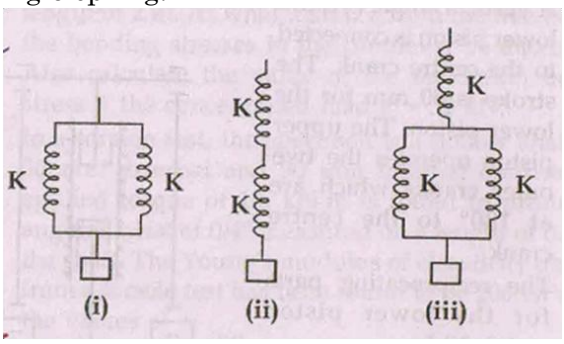
4. (a) The screw of a car lift has 150 mm dia. with square threads of 50 mm pitch and lead of 100 mm. Assume 1000 N is required for lifting of the car and thread friction coefficient is 0.20.

(i) Compute the torques required to rotate the screw to raise the car and lower the car. Also compute the overall efficiency of the screw.

(ii) What is the flaw in the above design? 15

(b) A simple gear train consists of three gears with 18, 16 and 72 teeth. The 18 teeth pinion is connected to a 4 kW electric motor running at 2400 rpm. Design the shaft for 72 teeth gear if the shearing stress is not to exceed 60 MPa in the shaft. 15

(c) Find the equivalent spring constant if the below shown spring systems are replaced by a single spring.



5

(d) Most of the times the rotating disc-shafts have keys; under such conditions it cannot be assumed that the shaft has a uniform cross-section. For such a disc-shaft system how will you determine the limits of speed for instability? 5

SECTION—C

5. (a) Explain the three types of oxy-acetylene flames. Indicate with the help of sketches the various zones, respective temperature ranges and applications of each type of flame. 20

(b) Explain the processes of extrusion given below. Indicate one typical product made through each of these processes:

(i) Direct Extrusion (ii) Indirect Extrusion

(iii) Hydrostatic Extrusion (iv) Impact Extrusion 20

6. (a) Determine the optimum cutting speed for an operation on a lathe machine using the following information:

Tool change time 3 min

Tool regrind time 3 min

Machine running cost Rs. 0.50 per min

Depreciation of tool regrind Rs. 5.0

The constants in the tool life equation are 60 and 0.2. 10

(b) (i) Why are the alignment tests done on machine tools?

(ii) Give the list of common testing equipment needed for alignment tests on a general purpose lathe.

(iii) Write steps to check straightness of carriage in a horizontal plane with the help of sketches. 15

(c) (i) What is the principle of metal removal in EDM process?

(ii) Describe the process with the help of sketch.

(iii) List advantages & limitations of the system. 15

7. (a) (i) List common time-series forecasting models. Explain simple exponential smoothing method of forecasting demand. What are its limitations?

(ii) The monthly forecasting and demand values of a firm are given below:

Month	Forecast Units	Demand Units
Jan	100	97
Feb	100	93
Mar	100	110
Apr	100	98
May	102	130
Jun	101	133
Jul	106	129
Aug	108	138
Sep	110	136
Oct	112	124
Nov	114	139
Dec	116	125

Calculate Tracking Signal for each month Comment on the forecast model. 10

(b) Four technicians are required to do four different jobs. Estimates of time to complete every job as provided by the technicians are as below:

Technician	Hours to complete Job			
	Job 1	Job 2	Job 3	Job 4
A	20	36	31	27
B	24	34	45	22
C	22	45	38	18
D	37	40	35	28

Assign the jobs to technician to minimize the total work-time. State the steps taken in the algorithm used. 15

(c) Prepare a flow chart and write a program in FORTRAN for the following problem:

The cutting tool life (T) for machining operation is given by Taylor's equation $vT^n = C$ where v is the cutting speed and C, n are constants. An MS workpiece of 50 mm dia. is turned with a carbide tool with n= 0.10 and C = 150. It is proposed to study the variation of tool life with the rpm of the workpiece at which turning is performed. Assume that the speed of spindle of lathe can be varied from 100 rpm to 2000rpm in the steps of 100 rpm. 15