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) A pressure cylinder of volume V contains air at pressure P_0 and temperature T_0. It is to be filled from a compressed air line maintained at constant pressure P_1 and temperature T_1. Show that the temperature of the air in the cylinder after it has been charged to the pressure of the line is given by

$$T = \frac{\gamma T_1}{1 + \frac{P_0}{P_1}\left[\gamma \frac{T_1}{T_0} - 1\right]}$$ 10

(b) Consider an engine in outer space which operates on the Carnot Cycle. The only way in which heat can be transferred from the engine is by radiation. The rate at which heat is radiated is proportional to the fourth power of the absolute temperature and to the area of the radiating surface. Show that for a given power output and a given T_1 the area of the radiator will be a minimum when $\frac{T_2}{T_1} = \frac{3}{4}$. 10

(c) A lead storage battery used in an automobile is able to deliver 5.2 MJ of electrical energy. This energy is available for starting the car. Let compressed air be considered for doing an equivalent amount of work in starting the car. The compressed air is to be stored at 7 MPa, 25°C. What is the volume of the tank that would be required to let the compressed air have an availability of 5.2 MJ? For air, Pv = 0.287 T, where T is in K, P in kPa, and v in m^3/kg. 10

(d) Obtain an expression for the specific work output of a gas turbine unit in terms of pressure ratio, isentropic efficiencies of the compressor and turbine and the maximum and minimum temperatures, T_3 and T_1. Hence show that the pressure ratio r_p for maximum power is given by

$$r_p = \left[\eta_T \eta_C \frac{T_3}{T_1}\right]^{\frac{\gamma}{2(\gamma-1)}}$$ 10

2. (a) An engine fitted with a single jet carburettor having a jet diameter of 1.25 mm has a fuel consumption of 6 kg/hr. The specific gravity of fuel is 0.7. The level of fuel in the float chamber is 5 mm below the top of the jet when the engine is not running. Ambient conditions are 1 bar and 17°C. The fuel jet diameter is 0.6 mm. The discharge coefficient of air is 0.85. Air-fuel ratio is 15. Determine the critical velocity of flow at throat and the throat diameter. Express the pressure at throat in mm of water column. Neglect compressibility effect. Assume discharge coefficient of fuel flow is 0.60. 15

(b) Find the percentage increase in the efficiency of a Diesel Cycle having a compression ratio 'r' of 16 and cut off ratio 'rc' is 10% of the swept volume, if C_v decreases by 2%. Take C_v = 0.717 kJ/kg°K and γ = 1.4. 15

(c) Explain the knocking phenomenon in a CI engine. Compare it with that of SI engines. Discuss the effect of operating variables on delay period and diesel knock. 10

3. (a) A steel pipe having internal diameter of 2 cm, outer diameter of 2.4 cm and thermal conductivity of steel of 54 W/mK carries hot water at 95°C. Heat transfer coefficient between the inner surface of steel pipe and the hot water is 600 W/m^{2}K. An asbestos insulation with thermal conductivity of 0.2 W/mK and thickness 2 cm is put on the steel pipe. Heat is lost from the outer surface of the asbestos insulated pipe to the surrounding air at 30°C, heat transfer coefficient for the outer surface of the insulation being 8 W/m^{2}K. Determine:

(i) The rate of heat transfer per meter length of the pipe.

(ii) Determine the temperatures at the inner, outer surfaces of the steel pipe and the outer surface of the insulation.

(iii) What do you understand by the term "critical radius of insulation? What is the value of critical radius in the above question? What is the rate of heat loss, if thickness of insulation were to correspond to critical radius?

Comment on the results. 10

(b) Define and discuss the physical significance of the following:

(i) Nusselt Number - Can It be less than 1?

(ii) Prandtl Number - What does it signify?

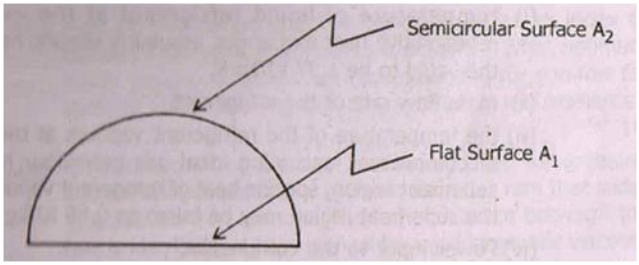
(iii) Biot Number - How does it differ from Nusselt number?

(iv) Thermal diffusivity

(v) Fin effectiveness. 10

(c) (i) State and explain Lambert law. How is it used in radiative heat transfer calculation? For a diffused flat surface having emissivity of 0.7 at temperature of 800°C, calculate normal intensity of radiation.
What would the intensity of radiation at an angle of 30° with respect to normal direction?

(ii) For a very long semicircular duct having surface areas A_2 and A_1 as shown below:



Determine shape factors F_{12}, F_{21}, F_{22}. 10

(d) (i) What is fouling in heat exchangers? How is it specified? How does the fouling affect the rate of heat transfer in heat exchangers?

(ii) Distinguish and differentiate between direct transfer heat exchangers and storage type heat exchangers with the help of simple sketches giving their advantages and disadvantages. 10

4. (a) A refrigeration system is to be designed for a cooling capacity of 7.5 tons of refrigeration at saturation pressure corresponding to –20°C. It uses refrigerant R-22. Condenser pressure is to be corresponding to saturation temperature of 40°C. The refrigeration system uses a liquid-vapour regenerative heat exchanger. The refrigerant vapours coming out of the evaporator are superheated by 5°C and then pass through the regenerative heat exchanger to cool the liquid refrigerant coming from the condenser. The temperature of the refrigerant vapours at the exit of heat exchanger is 20°C. The liquid refrigerant

is subcooled to 36°C at the exit of the condenser. Make a sketch of the system and represent it on P-h and T-S diagrams.

The system uses two single-acting cylinders with bore to stroke ratio of 0.8, speed of compressor is 1420 rpm, clearance factor for compressors is 0.04 and polytropic index of compression is 1.1. Mechanical efficiency of the compressor is 0.8.

Determine:

(i) Temperature of liquid refrigerant at the exit of regenerative heat exchanger, assuming specific heat of the liquid to be 1.37 kJ/kg K.

(ii) Mass flow rate of the refrigerant.

(iii) The temperature of the refrigerant vapours at the exit of compressor, assuming ideal gas behaviour in the superheat region, specific heat of refrigerant vapours in the superheat region may be taken as 0.85 kJ/kg K.

(iv) Power input to the compressor.

(v) COP of the system.

(vi) Volumetric efficiency of the compressor, and

(vii) Bore and stroke of the compressor.

The following properties of R-22 are given:

Sat. temp t_s	Sat. Pressure P_s	Sp. Vol. of Sat. vapour	Enthalpy (kJ/kg)	
			Sat. Liquid	Sat. vapour
°C	bar	m^3/kg	h_f	h_g
–20	2.448	0.0928	177.4	397.5
40	15.335	0.0151	249.08	415.95

For superheated refrigerant vapour at 2.448 bar and saturation temperature of –20°C.

Temperature	Specific volume	Enthalpy
°C	m^3/kg	kJ/kg
–15	0.0951	400.7
20	0.1107	423.9

20

(b) (i) Discuss the measurement of wet bulb temperature by means of a wick-covered bulb of a thermometer. How is it is related to dry bulb temperature and specific humidity of moist air and on what other factors does it depend?

(ii) Define thermodynamic wet bulb temperature. How is it determined? How does it differ from measured wet- bulb temperature? 10

(c) How do you define effective temperature as an index of comfort? On what factors does it depend? What optimum inside design conditions are recommended for comfort for summer air-conditioning including ventilation requirements? 10

5. (a) A hydraulic lift of the type commonly used for greasing automobiles consists of a 280 mm diameter ram that slides in a 280.18 mm cylinder. The annular space between the ram and cylinder is filled with oil having a kinematic viscosity of 0.00042 m^2/s and specific gravity of 0.86. If the rate of travel of the ram is 0.22 m/s, find the frictional resistance when 2 m of the ram is engaged in the cylinder. 5

(b) A solid, half-cylinder-shaped log of 0.48 M radius and 2.5 m long, floats in water with the flat face up.

(i) If the immersion depth of the lowest point is 0.3, what is the uniform specific weight of the log?

(ii) The log tilts about its axis (zero and net applied force), by less than 22°. Is it in stable equilibrium? Justify your answer with a sketch and logic.

(iii) If the log tilts by 18° (left side down; zero net applied force), what is the magnitude and sense of any moment that results? 15

(c) Air enters into a constant area frictionless duct with M = 3, P = 7 bar and T = 288 K. It is desired to reduce the flow Mach number to 2 at the exit of the duct.

Determine the amount of heat added and the corresponding change in pressure. For air, C_p = 1.003 kJ/kgK.
Take:

M	T_0/ T_0^*
3	0.6534
2	0.7934

10

(d) Show the basic elements of an electrostatic precipitation and explain its operation. 10

6. (a) A flow field is defined by u = 2y and v = xy. Derive expressions for the acceleration components. Find the magnitude of the velocity and acceleration at the point (2, 3). Specify units in terms of L and T. 5

(b) Derive an expression for small flow rates over a spillway, in the form of a function including dimensionless quantities. Use dimensional analysis with the following parameters:
Height of spillway = P
Head of spillway = H
Viscosity of liquid = μ
Density of liquid = ρ
Surface tension = σ
Acceleration due to gravity = g. 15

(c) Assume the velocity profile for turbulent flow in a circular pipe to be approximated by a parabola from the axis to a point very close to the wall where the local velocity is u = 0.6 u_m, where u_m is the maximum velocity at the axis. The equation for this parabola is

$$u = u_m [1 - 0.4(r/r_0)^2].$$

Find the value of kinetic energy correction factor. 15

(d) With the help of simple schematic flow diagrams, explain the difference between once-through steam generators and the drum type steam generators. 5

7. (a) For the velocity distribution prescribed by $u/u_0 = (y/\delta)^{1/7}$, show that the ratio of displacement thickness (δ^*) to momentum thickness (θ) is 1.285. 10

(b) A runner of a centrifugal pump has an outer diameter of 25 and runs at 1500 rpm. It has 10 blades, each of 5 mm thickness. They are backward facing at 30° to the tangent and the breath of the flow passages at outlet is 12.5 mm. Pressure gauges are fitted close to the pump casing on the suction and discharge pipes, both are 2.5 m above water level in supply sump. When discharge is 26 lit/s, the gauge reading are 4 m vacuum and 16.5 m of water respectively. Assume that there is no whirl at Inlet and no whirl slip. If 50% of velocity heat at from the volute, estimate: outlet the- runner is recovered as static head in
(i) theoretical head
(ii) manometric efficiency
(iii) losses in the impeller, and
(iv) capacity of the motor to drive the pump, if mechanical efficiency is 0.9. 20

(c) Show the velocity diagrams of a 50% reaction turbine operating with maximum blade efficiency and highlight its salient features. 10

8. (a) Application of dimensional analysis technique to compressible flow rotodynamic machines gives following dimensionless ratios:

(i) $\pi_1 = \dfrac{Q}{ND^3}$

(ii) $\pi_2 = \dfrac{gH}{N^2D^2}$

(iii) $\frac{\rho ND^2}{\mu}$

(iv) $\frac{P}{\rho N^3 D^5}$

Using them only:

(a) Show that

(i) π_1 represents condition of kinematic similarity

(ii) π_3 represents condition of dynamic similarity.

(b) Establish the expression of:

(i) unit speed, unit discharge and unit power for the turbine

(ii) specific speed for turbine and pump.

(c) Establish the effect of speed on discharge, heat developed and power required by pump. 15

(b) A constant area circular duct is connected to the convergent divergent nozzle exit. The air enters the nozzle from a tank at a pressure of 7 bar (ab) and temp, of 127°C. The pressure at the nozzle exit is 0.19 bar. If the temperature of the air is 3°C at the end of the duct, and the duct length is 17.5 diameter of the duct, find the friction co-efficient of the duct. Consider flow is adiabatic through a duct and isentropic in the nozzle.

Use:

M	4fLm/D
3	0.522
1.5	0.136

15

(c) Explain supersaturated expansion in case of flow through nozzle and discuss, briefly, the factors causing it. Represent the phenomenon on h-s diagram indicating superheated zone. State the effects of supersaturation. 10

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) (i) Define "Stability", and "Isochronism" for spring controlled governor.

(ii) Draw the controlling force vs. radius of rotation of governor ball for unstable, stable and isochronous governor.

(b) A crank and slotted lever Quick Return Motion Mechanism used in a shaping machine has a distance of 200 mm between the centre of oscillation 'A' of the slotted lever and the centre of rotation 'B' of the crank. The radius of the crank BC is 100 mm.

(i) Show on a diagram the extreme positions of the lever ah during one complete rotation of the crank.

(ii) Find the ratio of the time of cutting to the time of the return stroke.

(c) (i) What is critical damping for a spring dashpot and mass vibrating system?

(ii) Such a system has mass m = 10 kg, spring stiffness k = 4000 N/m and damping coefficient c = 40/m/s. Find the critical damping coefficient and the damping factor.

(d) A tapered bar 200 mm long, tapers uniformly from a diameter of 40 mm to a diameter of 20 mm over its axial length. If an axial compressive force of 10 kN is applied on the bar, what is the strain energy absorbed in the bar? E = 100 kN/mm^2.

(e) A cantilever AB, 5 m long is fixed at end A. At end B, an upward load of 2 kN is applied. At point C, 2 m from end B, a downward load of 2 kN is applied. Draw the bending moment diagram of the cantilever.

(f) A thin cylindrical shell of diameter 200 mm, wall thickness t is subjected to an internal pressure of 2 N/mm^2. The longitudinal joint efficiency of the shell is 80%. What should be the minimum wall thickness of shell, if allowable stress in shell is limited to 100 MPa?

(g) Explain how grain refinement improves the strength of a polycrystalline material.

(h) Stub tooth spur gears are preferred for medium and heavy duty applications. Justify this statement in about 20 words.

(i) Which theory of failure will result in economic shaft design?

(j) Why are V-belts used in short centre drives?

(k) What is meant by allotropism? What is its importance?

(l) List four undesirable affects of decarburization of steels after heat treatment.

(m) Name four fibre materials generally used in metal-matrix composites.

(n) Enumerate four defects caused due to residual stresses in welded joints.

(o) What is isostatic pressing of metal powders? What are its advantages?

(p) What is critical ratio in scheduling? What is the meaning of critical ratio

scheduling value of 2?

(q) What are the steps involved in method study?

(r) What are the methods of finding initial solution in transportation problems?

(s) A company purchases a product at Rs. 50 per unit and sells it at Rs. 90 per unit. The hiring charges for storing the unit are Rs. 20,000. Determine the number of units to be sold to achieve break-even. If the company sells 750 units, calculate the margin of safety.

(t) An array of 50 integer numbers is to be read by using Fortran program. Write the program lines for the same

SECTION—B

2. (a) Three steel tubes of outer diameter 20 mm and inner diameter 16 mm each are welded together so that their centres form an equilateral triangle of side 20 mm. Three meter length of this composite tube is used as a simply supported beam at ends with a central point load. How much point load can be applied if the maximum stress in beam sections is not to exceed 100 MPa? 10

(b) Two bevel gears A and B (having 60 teeth and 40 teeth, respectively) are rigidly mounted on two co-axial shafts X and Y as shown in Figure 2(b). A bevel gear C (having 50 teeth) meshes with A and B and rotates freely on one end of an arm. At the other end of the arm is welded a sleeve and the sleeve is riding freely loose on the axes of the shafts X and Y. If the shaft X rotates at 120 r.p.m. clockwise and the arm rotates at 120 r.p.m. anticlockwise, find the speed of shaft Y.

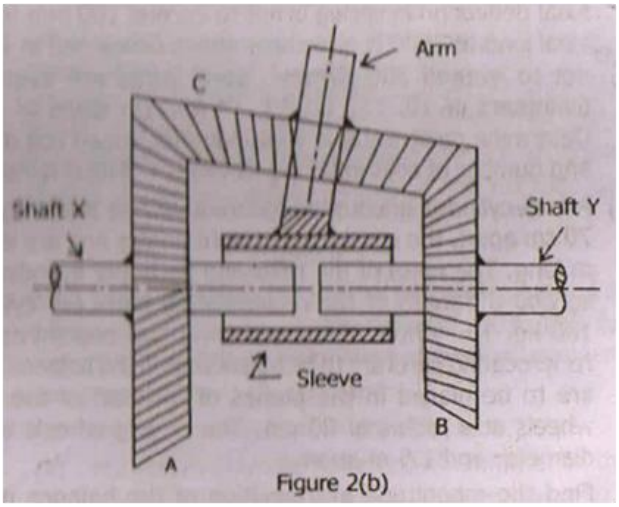


Figure 2(b)

10

(c) A hollow shaft whose ratio of internal diameter to external diameter (k) is 0.5, transmits 1.5 kW at 1400 rpm. At a certain section it is also subjected to a bending moment of 5 N.m. The shaft is to be made from chrome-vanadium steel having allowable shearing stress of 200 MPa.

Design the shaft using the ASME code formula for transmission shafting as given below:

$$D_0 \text{ (outer diameter)} = \left[\frac{16}{\pi\tau_{all}}\left(C_m M^2 + C_t T^2\right)\frac{1}{1-k^4}\right]^{1/3}$$

Combined shock and fatigue factor for bending moment (C_m) is 1.5.

Combined shock and fatigue factor for torque (C_t) = 1.0.

Determine the internal and outer diameter of the shaft. 15

(d) What are superalloys? Name 3 superalloys. Give composition of Nimonic alloy. 5

3. (a) Design a close coiled helical spring to have spring index of 8. Axial deflection in spring is not to exceed 100 mm under an axial load of 2600 N and shear stress developed in spring is not to exceed 300 N/mm^2. Steel wires are available in diameters of 10, 11, 12, 13, 14 mm (in steps of 1 mm). Determine most suitable wire diameter, mean coil diameter and number of coils in spring. Given G =

84000 N/mm^2. 10

(b) A two-cylinder uncoupled locomotive has inside cylinders 70 cm apart, the cranks are at right angles and are each 0.3 m long. The mass of the revolving parts per cylinder is 160 kg and the mass of the reciprocating parts per cylinder is 180 kg. The whole of the revolving and two-thirds of the reciprocating parts are to be balanced and the balance masses are to be placed in the planes of rotation of the driving wheels at a radius of 80 cm. The driving wheels are 2 m diameter and 1.5 m apart.
Find the magnitude and position of the balance masses. The driving crank speed is 300 r.p.m. 15

(c) Draw a neat sketch of a cotter joint and show how its various elements are likely to fail under tensile loading. Give one engineering application of this joint. 5+4+1

(d) What is Bauschinger's effect? Make a neat sketch of stress-strain diagram and explain how yield strength in compression is reduced than the yield strength in tension. 5

4. (a) Considering principal stresses in a steam boiler drum as P, 0.5P, 0 and Poisson's ratio $\mu = 0.30$, equivalent stress in simple tension as σ, find P in terms of σ due to (i) maximum shear stress theory, (ii) strain energy theory, (iii) distortion energy theory. 10

(b) A steam engine develops 300 kW at 120 r.p.m. The coefficient of fluctuation of energy as found from the turning moment diagram is to be 0.1 and the fluctuation of speed is to be kept within ± 1% of the mean speed. Find the mass of the flywheel required, if the radius of gyration is 2 m. 10

(c) (i) What are common modes of failure of rolling element bearings?
(ii) Write a brief comment on the holding torque acting on epicyclic gear train casings. 5 + 5

(d) What is ductile SG iron? What is the purpose of adding magnesium or cerium in molten metal? Why is its tensile strength more than the tensile strength of grey cast iron? When the metal is cooled fast from molten state, what type of microstructure is obtained? Make an approximate sketch of microstructure indicating the microconstituents. 10

SECTION—C

5. (a) A 12.5 mm diameter of rod is to be reduced to 10 mm diameter by drawing in a single pass at a speed of 100 m/min. Assuming a die angle of 5° and coefficient of friction between the die and steel rod as 0.15, calculate:
(i) the power required in drawing.
(ii) maximum possible reduction in diameter of the rod.
(iii) if the rod is subjected to a back pressure of 50 N/mm^2.
What would be the draw stress and maximum possible reduction?
Take stress of the work material as 400 N/mm^2. 15

(b) A round casting is 20 mm in diameter and 50 mm in length. Another casting of the same metal is elliptical in cross-section, with a major to minor axis ratio of 2, and has the same length and cross-sectional area as the round casting. Both pieces are cast under the same conditions. What is the difference in the solidification times of the two castings? 10

(c) Discuss the process capabilities and applications of Gas Metal Arc Welding, Gas Tungsten Arc Welding, and Diffusion Bonding processes. 15

6. (a) Discuss the effects of the following elements on the machinability of steels: 5
(i) Aluminium and Silicon
(ii) Sulphur and Selenium
(iii) Lead and Tin
(iv) Carbon and Manganese
(v) Molybdenum and Vanadium

(b) Discuss the effects of inefficient dielectric and electrolyte circulation in the inter-electrode gap on the Electric Discharge Machining and Electro Chemical Machining processes respectively. 5

(c) Why are tools coated? What are the common coating materials? 5

(d) What is creep feed grinding? Discuss its salient features, advantages and application. 10

(e) With the help of a neat sketch, explain the working of a diamond pin locator. 5

(f) (i) State the methods of defining line segment of cutter motion using APT program format. 5

(ii) The Table of a CNC machine is driven by a Lead screw which is rotated by a DC servomotor. A digital encoder which emits 1000 pulses per second is mounted on the lead screw as a feedback device. If the lead screw pitch is 6 mm and motor rotates at 500 rpm, find:

1. Basic Length Unit (BLU) of the system.
2. Linear velocity of the table.
3. Frequency of pulses generated by the feedback device. 5

7. (a) A machine is used for turning operation and it takes 30 minutes to machine the component. Efficiency of the machine is 80% and scrap is 25%. The desired output is 1200 pieces per week. Considering 40 hours per week and 50 weeks in a year, determine the number of machines required in a year. 5

(b) Draw the flow chart for solving assignment problems by Hungarian method. 15

(c) Explain least square method of forecasting. 10

(d) Group the following variables as integer and real variables in FORTRAN program language: 10

(i) NSUM
(ii) KMAX2
(iii) DIA 24
(iv) LOAD 3
(v) THETA 5
(vi) COS
(vii) EPSON
(viii) RUPEE
(ix) NUMR
(x) MOMENT