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) Derive the following Clapeyron and Clausius-Clapeyron equations:

$$\frac{dP}{dT} = \frac{h_{fg}}{T(v_g - v_f)}, \quad \text{and} \quad \frac{dP}{P} = \frac{h_{fg}}{RT^2} dT$$

Explain the physical significance of these equations.   10

   (b) A heat pump operates between two identical bodies. In the beginning, both the bodies are at the same temperature T_1 but operation of heat pump cools down one of the body to temperature T_2. Show that for the operation of heat pump the minimum work input needed by the heat pump for unit mass is given

$$W_{min} = C\left[\frac{T_1^2}{T_2} + T_2 - 2T_1\right]$$

where c is the specific heat of bodies. Discuss whether the system satisfies first and second law of thermodynamics or not.   10

   (c) A large vessel contains steam at a pressure of 20 bar and a temperature of 350°C. This large vessel is connected to a steam turbine through a valve followed by a small initially evacuated tank with a volume of 0.8 m3. During emergency power requirement, the valve is opened and the tank fills with steam until the pressure is 20 bar. The temperature of the tank is then 400 °C. Assume that the filling process takes place adiabatically and the changes in potential and kinetic energies are negligible. By drawing the control volume, calculate the amount of work developed by the turbine in kJ.   20

2. (a) What does a catalyst perform in a catalytic convertor?
   Discuss the oxidation and reduction reactions that are taking place in a convertor. Why it is preferred to use unleaded petrol in cars equipped with a catalytic convertor system?   15

   (b) "Factors which increase detonation in S.I. engine tends to reduce knocking in C.I. engines", discuss the validity of the statement.   5

   (c) A six cylinder, four stroke spark-ignition engine of 10 cm × 12 cm (bore/stroke) with a compression ratio of 6 is tested at 4800 rpm on a dynamometer of arm 55 cm. During a 10 minutes test, the dynamometer reads 45 kg and the engine consumed 5 kg of petrol of calorific value 45 MJ/kg. The carburettor receives the air at 29°C and 1 bar at the rate of 10 kg/min. Calculate:
   (i)   the brake power
   (ii)   the brake mean effective pressure
   (iii) the brake specific fuel consumption
   (iv)   the brake specific air consumption
   (v)   the brake thermal efficiency

(vi) the air-fuel ratio   20

3. (a) List the factors which are considered in the optimum design of fins.   3
    (b) An electronic semi-conductor device generates heat equal to 480×10^{-3} W. In order to keep the surface temperature at the upper safe limit of 70°C, the generated heat has to be dissipated to the surrounding which is at 30°C. To accomplish this task, aluminium fins of 0.7 mm square and 12 mm long are attached to the surface. The thermal conductivity of aluminium fins is 170 W/mK. If the heat transfer coefficient is 12 W/m²K, calculate the number of fins required. Assume no heat loss from the tip of fins.   7
    (c) A commercial aeroplane is modelled as a flat plate which is 1.5 m wide and 8 m long in size. It is maintained at 20°C. The aeroplane is flying at a speed of 800 km/h in air at 0°C and 60 cm of Hg pressure. Calculate the heat loss from the wing if the flow is made parallel to the width of the wing. Take thermo-physical properties of air at the mean film temperature of 10 °C as
    K = 2.511×10^{-2} W/mK, W= 14.16×10^{-6} m²/s, Pr = 0.705.   15
    (d) An electrically heated industrial furnace cavity is modeled in the form of a cylinder having diameter 10 cm and length 20 cm. It is opened at one end of surroundings that are at a temperature of 300 K. The electrically heated sides and the bottom of the cavity which are well insulated and may be approximated as black bodies are maintained at a temperature of 1800 K and 2000 K, respectively. By showing the sketch of the furnace, find the power required to maintain the surface at this condition. Take shape factor from the bottom surface to surroundings as 0.06.   15

4. (a) Discuss in detail the factors affecting the performance of vapour compression refrigeration cycle.   15
    (b) Explain how a refrigerant produces cooling effect. What are the good qualities of refrigerant? Name the refrigerant which does not destroy ozone layer.   10
    (c) 10 tons of refrigeration is required for a food storage space to keep the food stuff cool. The refrigerant used in the plant is Freon-12 and is subcooled by 5°C before entering in the expansion valve. The temperature of evaporator and condenser are -8°C and 30°C respectively. The vapour is superheated to 6°C before leaving the evaporator coil. The compressor is of two cylinders, single acting type having stroke equal to 1.5 times the bore. The compressor runs at 800 rpm and the compression is assumed to be isentropic. Estimate the following:
    (i)   refrigerating effect per kg
    (ii)   mass flow rate of the refrigerant
    (iii) theoretical piston displacement
    (iv)   theoretical power
    (v)   C.O.P. and
    (vi)   theoretical bore and stroke of the compressor.   15

5. (a) Obtain an expression for discharge through an orifice meter.   10
    (b) A hollow cylinder of 1 m long has an internal diameter and external diameter equal to 0.4 m and 0.6 m, respectively and both ends are open. Assuming the weight of the cylinder as 700 M, analyze whether the cylinder would be stable while floating in water with its axis vertical.   10
    (c) Show that the hydraulic efficiency of a Pelton turbine is maximum when peripheral wheel velocity is half the absolute velocity of jet at inlet. Further, show that

$$\eta_{h,\max} = \frac{1 + K \cos \beta_2}{2}$$

    where K is the friction factor.
    Mention the criteria for selecting water turbines for hydel power plant.   20

6. (a) Develop an expression for the pressure loss across a conical contraction of diameter D_1 and D_2 in a given length L for a laminar flow. Explain the physical significance of equation. **10**

(b) Do you need priming in a gear pump? Give the reasons for your answer. **5**

(c) Explain the separation of flow and discuss the methods used for controlling of separation in a diffuser. **10**

(d) A centrifugal pump is to discharge 0.2 m³/s at a speed of 1400 rpm against a head of 25 m. The impeller diameter is 0.3 m, its width at outlet is 0.05 m and the manometric efficiency is 80%. Determine the vane angle at the outer periphery of the impeller and label the angle by sketching the impeller. **15**

7. (a) What do you mean by supersaturated flow through steam nozzles? Discuss the causes of supersaturation phenomena. **10**

(b) What is the basic principle of regenerative feed heating in steam power plant cycle? Sketch a practical feed heating system for a 500 MW steam turbine and label it. **10**

(c) A blade group in a Parson's reaction steam turbine is of constant height. The turbine develops 60 MW running at 3000 rpm. The initial steam pressure and temperature entering the turbine are 50 bar and 400°C and the back pressure is 70 cm Hg. The efficiency ratio of turbine is 70%. The mean blade velocity in the group is 120 m/s. The average specific volume of steam in the group may be taken as 0.62 m3/kg. By drawing the velocity diagram, calculate the following:
(i) mass flow rate of steam
(ii) height of blade
(iii) drum diameter
(iv) moving outlet blade angle
Assume the ratio of blade velocity to steam velocity as 0.55 and the nozzle (fixed blade) angle is 20°. Neglect the tip leakage and mechanical losses. **20**

8. (a) Why should no moisture flow along with steam from the drum to the superheater and why is no vapor bubble desired to flow along with saturated water from the drum to the downcomers? **5**

(b) With the help of a neat sketch discuss the working principle of Velox high pressure boiler. **15**

(c) A simple open cycle gas turbine has a compressor turbine and a free power turbine. It develops electrical power output of 250 MW. The cycle takes in air at 1 bar and 288 K. The total compressor pressure ratio is 14. The turbine inlet temperature is 1500 K. The total to total isentropic efficiency of compressor and turbine at 0.86 and 0.89, respectively. The mechanical efficiency of each shaft is 0.98. Combustion efficiency is 0.98 while combustor pressure loss is 3% of compressor delivery pressure. The exhaust pressure loss is 0.03 bar. Alternator efficiency is 0.98. Take calorific value of fuel equal to 42,000 kJ/kg, C_{pa} = 1.005 kJ/kgK and C_{pg} = 1.15 kJ/kgK. Calculate the following:
(i) air-fuel ratio
(ii) specific work output
(iii) specific fuel consumption
(iv) mass flow rate of air
(v) cycle thermal efficiency. **20**

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) Which one of the three shafts listed here has the highest ultimate tensile strength? What is the approximate carbon content in each steel?
     (i) Mild steel (ii) Cast iron (iii) Spring steel
   - (b) State the Von - Mises's theory. Also give the mathematical expression.
   - (c) Why are shafts not made out of cast iron?
   - (d) When are I-Sections preferred in engineering applications? Elaborate your answer.
   - (e) For the three velocity ratios specified below which one of the following gear drive would be preferable for transmitting power with reductions at 4, 20 and 70?
     The drives are single stage spur gear reduction, single start warm drive and triple start warm drive.
   - (f) In a single involute gear already manufactured of the three diameters given below two are pre-determined.
     Which are those two? Substantiate your answer.
     The three diameters given are adandem circle diameter, pitch circle diameter and base circle diameter.
   - (g) In an epicyclic gear train the number of planets in any row has to be more than one. Do you agree or disagree. Why?
   - (h) In a typical power transmission from an induction motor running at 1440 rpm to an output speed of 1 rpm. Which order of reduction of the three drives listed below is preferred? Why?
     War gear reduction, belt reduction and spur gear reduction.
   - (i) Is the Cam in mesh with the follower a case of complete constraint? Substantiate your answer.
   - (j) Do you agree that in a four stroke four cylinder I.C. engine the primary forces and the primary couples are in balance? Substantiate your answer.
   - (k) Distinguish between unilateral and bilateral tolerances for the dimensions. Indicate the tolerance zones for each by taking an example.
   - (l) What is the hole basis and shaft basis of fits? Which one is preferred in practice and why?
   - (m) Write the chemical equation for the reaction going on in the oxy-acetylene flame. Where do you get the most part of the oxygen, is it from the cylinder or the atmosphere?
   - (n) Clearances have to be provided on the press tools, what is the order of clearances for shearing operation and deep drawing operation? On what tool will you provide the clearance in

       (i)   Punching operation
       (ii) Blanking operation

(o)   What is a three high rolling mill? Indicate the movement of rolls and the workpiece.

(p)   What is the basis for Selective Inventory Control? Mention four applications of the same in the Inventory Management.

(q)   What is the distribution followed by the activity durations of a PERT network? Mention its mean and standard deviation.

(r)   What do you understand by tracking signal in forecasting? How is it computed?

(s)   Distinguish between P-system and Q-system in Inventory Control.

(t)   What are the characteristics of cellular manufacturing system?

SECTION—B

2. (a)   An antrifriction bearing used in a gear box has a specification 6108. What do the numbers 6, 1 and 08 signify?   12

    (b)   Mention three different methods used to prevent an antifriction bearing from sliding axially in a shaft at the inner race and in a bore at the outer race.   18

    (c)   Which one of the three bearings listed below will you choose to take a heavy axial load on the bearing (i) self aligning ball bearing (ii) deep groove ball bearing (iii) Thrust bearing.
        Give reasons for your selection.   10

3. A single cylinder engine and a four cylinder in line four stroke engine (both horizontal) are running at speed of 1500 rpm. Crank radius and connecting rod for both are 100 and 500 mm respectively. Reciprocating parts for the single cylinder engine weigh 160 N and for each of the four cylinders of the four cylinder engine weigh 40 N. Revolving masses for both single and four cylinder engines work out to 160 N with a net eccentricity of 0.1 mm. Compute the following for both the engines:

    (i)   Magnitude, frequency and direction of the predominant unbalanced force due to the reciprocating parts.   18

    (ii) Magnitude, frequency and direction of the unbalanced force due to the revolving parts.   18

    (iii) If a vibration pick up is used to measure the vibration signals on the frame of the engine, direction in which the signals will be predominant.   4

Expression for the piston acceleration is given by

$$\omega_r^2\left(a_0 + a_1\cos\theta + a_2\cos2\theta + a_4\cos4\theta\right)$$

where ω is the crank speed in rad/s, r crank radius, $a_0 = 0$, $a_1 = 1$, $a_2 = 0.2$ and $a_4 = 0.002$, θ-the crank angle.

4. A hot rolled steel shaft is subjected to a torsional load that varies from 300 KNmm clockwise to 100 KNmm anticlockwise as an applied bending moment at a critical section varies from +400 KNmm to –200 KNmm. The shaft is of uniform cross-section and no key-way is present at the critical section. Determine the required shaft diameter by taking factor of safety 1.5. For the material, take ultimate tensile stress as 560 MPa, stress at yield point 420 MPa design stress is 280 MPa.
Also take the modification factor as 0.62, size correction factor as 0.85, the load factor for bending as 1 and the load factor for torsion as 0.58.   40

SECTION—C

5. (a)   What are the velocities which come into existence when a metal is cut orthogonally? Show these velocities graphically on a velocity diagram and determine the mathematical relationship in terms of shear and rake angles.

    (b)   Distinguish between a jig and fixture, with the help of diagrams for at least five each.   40

6. (a) What are the steps involved in making of carbide tool bits? What do you understand by the green density of a metal powder compacted part? What are the chief merits of a bush made by metal powder compaction. 20

(b) The demand for a product during the last 10 years is given below. Estimate the demand for the next two years by the method of regression.

Year	1	2	3	4	5	6	7	8	9	10
Units	124	135	145	150	167	157	161	170	187	168

15

(c) Define Value Engineering. What are the conditions conducive to take up VA/VE study. 5

7. (a) In a machine shop, certain type of machines break-down at an average rate of 6 per hour. The breakdowns are in accordance with Poisson process. The estimated costs of idle machine is Rs. 15 per hour. Two repairmen A and B with different skills are being considered to be hired as repairmen. Repairman A takes six minutes on an average to repair a machine and his wages are Rs. 8 per hour, whereas the repairman B takes five minutes to repair and the wages are Rs. 10 per hour. Which repairman's service should be used and why? Assume the work shift of 8 hours. 20

(b) For xyz company, the annual requirement of an item is 2400 units. Each item costs the company Rs. 6. The supplier offers a discount of 5% if 500 or more quantities are purchased. The ordering cost is Rs. 32 per order and the average inventory cost is 16%. Is it advisable to accept the discount? Comment on the result. 20