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,* $\gamma = 1.4$, $M = 28.97$ *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) An ideal gas is heated from temperature T_1 to T_2 by keeping its volume constant. The gas is expanded back to its initial temperature according to the law pv^n = constant. If the entropy changes in the two processes are equal, find the value of n in terms of the adiabatic index γ. 5

(b) A cylinder contains one kg of water and steam at a pressure of 3.8 bar and 0.4 dry. Heat is supplied at constant volume until the pressure reaches to 10 bar. The steam is then expanded according to the law pv = constant, until the pressure is 2 bar. Calculate
(i) Heat transfer during constant volume heating.
(ii) Heat transfer during pv = constant expansion.
(iii) Temperature of steam after the expansion. 15

(c) An adiabatic cylinder of volume 10 m^3 is divided in to two compartments A and B, each of volume 6 m^3 and 4m^3 respectively, by a thin sliding partition. Initially the compartment A is filled with air at 6 bar and 600 K, while there is a vacuum in the compartment B. Suddenly the partition is removed, the fluid in compartment A expands and fills both the compartments. Calculate the loss in available energy. Assume atmosphere is at 1 bar and 300 K. 20

2. (a) The factors that tend to increase detonation in SI Engine tend to reduce knocking in CI engine. Discuss this statement with reference to the following influencing factors:
(i) compression ratio
(ii) inlet temperature
(iii) self-ignition temperature of fuel
(iv) time lag of ignition of fuel, and
(v) combustion chamber wall temperature. 10

(b) Derive an expression for air standard efficiency of the following cycle in terms of compression ratio, R, CV and γ.
(i) an isothermal compression, compression ratio, y
(ii) an increase of pressure at constant volume
(iii) an adiabatic expansion. 10

(c) During the trial of a single-acting oil engine, cylinder diameter 20 cm, stroke 28 cm, working on the two-stroke cycle and firing every cycle, the following observations were made:
Duration of trial, 1 hour
Total fuel used, 4.22 kg;
Calorific value,44670 kJ/kg;
Proportion of hydrogen in fuel, 15%

Total number of revolutions, 21000
Mean effective pressure, 2.74 bar
Net brake load applied to a drum of 100 cm diameter, 600N
Total mass of cooling water circulated, 495 kg
Temperature of cooling water: inlet 13° C, outlet 38°C
Air used, 135 kg.
Temperature of air in test room, 20°C and temperature of exhaust gases, 370°C
Assume: $C_{p\ gases}$ = 1.005 kJ/kg K and $C_{P\ steam}$ at atmospheric pressure = 2.093 kJ/kg K.
Calculate the thermal efficiency and draw up the heat balance. 20

3. (a) Sketch and describe the working of a once through boiler. Discuss its special features. 10

(b) Discuss an ideal regenerative cycle for a steam plant. Why is ideal cycle not possible in practice? 10

(c) In a two-stage velocity compounded impulse turbine the steam leaves the nozzles at a velocity of 675 m/s, when the blade speed is 150 m/s. The nozzle angle is 20°, while the discharge angles are: 25° for the first row blades, 25° for the fixed blades and 30° for the second row blades. There is a 10 percent drop in velocity during passage of steam through each row of blades. For the steam flow rate of 5 kg/s, calculate the power output of the turbine and the diagram efficiency. Also calculate the length of are occupied by the nozzles if their height is 25 mm. Steam is supplied to the stage at 12 bar, 300°C. 20

4. (a) Derive an expression, in terms of initial and final pressures and the volume of air drawn in per stroke, for the minimum work done in the two-stage compression of air. Assume adiabatic compression and perfect intercooling. Neglect clearance and show clearly all the steps in the analysis. 10

(b) A jet engine is flying at 300 m/s when the pressure and temperature of the atmosphere are 0.8 bar and 230 K respectively. The compressor pressure ratio is 4/1 and the maximum cycle temperature is 1000 K. Calculate, specific thrust, power produced, propulsive efficiency, overall thermal efficiency and the fuel consumption.
Assume: isentropic efficiency of components unity; nozzle throat area 0.06 m^2; calorific value of fuel 43000 kJ/kg; C_p and γ for the compression process 1.005 kJ/kgK and 1.4; C_p and γ for the combustion and expansion processes 1.15 kJ/kgK and 1.333. 30

5. (a) A food storage locker requires a refrigeration capacity of 50 kW. It works between a condenser temperature of 35°C and an evaporator temperature of –10°C. The refrigerant is ammonia. It is subcooled by 5°C before entering the expansion valve by the dry saturated vapour leaving the evaporator.
Assuming a single cylinder, single-acting compressor operating at 1000 rpm with stroke equal to 1.2 times the bore, determine (a) the power required, and (b) the cylinder dimensions.

Saturation Temperature	Pressure	Enthalpy		Entropy		Specific volume		Specific heat	
		kJ/kg		kJ/kg K		m^3/kg		kJ/kg K	
° C	bar	Liquid	Vapour	Liquid	Vapour	Liquid	Vapour	Liquid	Vapour
–10	2.9157	154.056	1450.22	0.82965	5.7550	-	0.417477	-	2.492
35	13.522	366.072	1488.57	1.56605	5.2086	1.7023	0.095629	4.556	2.903

20

(b) What is impulse function? Show that

$$\frac{F}{F^*} = \frac{1+\gamma M^2}{M\sqrt{\left[2(1+\gamma)\left(1+\frac{\gamma-1}{2}M^2\right)\right]}}$$

(c) A supersonic aeroplane flies at a Mach number 1.8 at an altitude of 700 m,

where the atmospheric temperature is 10°C. What is the time that elapses, by which the acoustic disturbance reaches an observer on the ground after it is directly overhead? 10

6. (a) For the data given below for a Pelton turbine, calculate the friction factor for the buckets, hydraulic efficiency and mechanical efficiency. Overall efficiency, 0.82; speed ratio,0.45; coefficient of velocity, 0.98; jet deflection angle, 160°; windage and bearing friction losses ∝ (rotational speed)^2; volumetric efficiency, 1. 20

(b) 300 m^3/min of air at 10° c dry bulb temperature and 90% relative humidity is to be heated and humidified to 35°C drybulb temperature and 22.5°C wet bulb temperature. The required conditions are achieved by heating, humidifying and then again by heating. The relative humidity of the air coming out of the humidifier is 90%. Find

(i) the heating capacity of the first heater and the by-pass factor if the surface temperature of the coil is 40° C

(ii) the capacity of the humidifier in kg/hour

(iii) the heating capacity of the second heater and the coil surface temperature if the bypass factor is 0.5, and

(iv) the humidifying efficiency of air washer (humidifier). 20

7. (a) Derive from the first principles the Euler's equation of motion for steady flow along a streamline. Obtain Bernoulli's equation by its integration. State the assumptions made. 10

(b) A cubical tank has sides of 2 m. Upto a height of 0.8 m it is filled with water and the rest space is filled with oil of specific gravity 0.85. For one vertical side calculate

(i) the total pressure, and

(ii) the position of the centre of pressure. 10

(c) The velocity distribution in a pipe is given by

$$\frac{u}{u_s} = 1 - \left(\frac{r}{R}\right)^n$$

where u_s is the maximum velocity at the centre of the pipe, u is the velocity at a distance r from the centre and R is the pipe radius. Obtain an expression for the mean velocity in terms of u_s and n. 10

(d) Explain what is meant by separation of boundary layer. Describe with sketches the methods to control separation. 10

8. (a) During an experiment to measure the temperature of hot gas flowing through a large pipe with a small thermocouple located centrally in the pipe, the following date were obtained under the steady state conditions.
Velocity of gas in the pipe line, 4 m/s
Temperature of pipe wall, 400°C
Temperature indicated by the thermocouple, 580°C
Diameter of the thermocouple junction, 1.5 mm
Emissivity of the thermocouple, 0.3
Calculate the true gas temperature.
The convective heat transfer coefficient-can be calculated from $Nu_d = 0.5\ Re_d^{1/2}$
The property values may be used at 400°C and are:
$k = 49.72 \times 10^{-3}$ W/m °C, $\mu = 32.68 \times 10^{-6}$ kg/mss; $\rho = 0.5224$ kg/m^3.
Comment on the methods by which accuracy of the thermocouple reading can be improved. 10

(b) Air flows through a 25 mm diameter tube with a mean velocity of 30 m/s. The tube wall temperature is 280°C and the air temperature increases from 20° C to 260°C. Using the simple Reynolds analogy calculate, the length of the tube required and the pumping power. For turbulent flow in a tube, take

$$f = \frac{0.046}{\mathrm{Re}_d^{0.2}}$$

Properties may be taken at the mean film temperature and from the Tables these are:

k = 38.45 × 10^{-3} W/m °C; C_p = 1.0268 kJ/kg °C; ρ = 0.7306 kg/m^3; μ = 26.17 × 10^{-6} kg/ms. 20

(c) For forced convection heat transfer, when factional heating in the fluid cannot be neglected, show by dimensional analysis

$$Nu = f\left[\mathrm{Re}, \mathrm{Pr}, \frac{C^2}{C_p T}\right]$$

Discuss the physical significance of each term. 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) Write the number of degrees of freedom constrained in each case by the kinematic pairs
(i) Revolute pair (ii) Cylindrical pair(iii) Screw pair (iv) Spherical pair

(b) A rigid link placed on a smooth horizontal plane is struck by an impulsive force at a point 20 cm distant from its e.g., such that it starts rotating about a point 5 cm away from the e.g. Determine the radius of gyration of the link and comment on the relative location of three points, viz. point of force application, e.g. and point of rotation.

(c) Male the conditions for a rigid rotor to be dynamically balanced.

(d) Show graphically the variation of the ratio of damped frequency to undamped frequency against damping ratio in case of a damped oscillator.

(e) The tight side and slack side tensions in a running belt derive are respectively T_1 and T_2. What would be the belt tension, when the drive stops?

(f) Determine the torsional stiffness of a hollow shaft of length L and having outside diameter equal to 1.5 times inside diameter d. The Shear modulus of the material is G.

(g) A uniform cantilever beam (EI constant) of length L is carrying a concentrated load P at its free end. What would be its slope at the (i) free end (ii) built-in end.

(h) If the Poisson ratio of an elastic material is 0.3, determine the ratio of its elastic modulus to its shear modulus. Write the formula you use.

(i) How are unilateral and bilateral tolerances indicated on dimensions of a component? Illustrate each with an example.

(j) Two materials as per BIS system of designation are
(i) FG 35 Si 15 (ii) Cu Zn 42 Pb2
Name them with comple specifications.

(k) Specify the ball size and the magnitude of load applied in case of Brinell hardness tester.

(l) What are Vents and Chills in mould?

(m) In a surface grinding operation of a workpiece of size 20 cm (length) × 10 cm (width), the speed of table is 25 m/min and feed is 0.2 mm/Stroke. Determine the time for grinding single surface in a single cut.

(n) What is gang milling?

(o) Define the following statements as given in APT language
(i) C1 = CIRCLE / CENTER, P1, TANTO, L1
(ii) FEDRAT/4.0

(p) What do the following symbols imply in 'Work Study?

(q) An item can be produced at a fixed cost of Rs. 80,000 per annum and a unit variable cost of Rs. 40. If the selling price per item is Rs. 60, determine the breakeven production volume.
(r) Give two situations, where you would prefer CPM to PERT.
(s) Distinguish between Quality Assurance and Quality Control.
(t) Name the two important constituents of CPU in a computer.

SECTION—B

2. (a) A square threaded bolt of mean diameter 24 mm and pitch 5 mm is tightened by screwing a nut, whose mean diameter of bearing surface is 50 mm. If the coefficient of friction for nut and bolt is 0.1 and that for nut and bearing surface is 0.15, find the force required at the end of a spanner 0.5 m long, when the load on the bolt is 12 kN. 15

(b) In a spring controlled governor of the Hartung type, the lengths of the horizontal and vertical arms of the bell crank levers are 100 mm, and 80 mm respectively. The fulcrum of the bell-crank lever is at a distance of 120 mm from the axis of the governor. Each revolving mass is 8 kg. The stiffness of the spring is 20 kN/m. If the length of each spring is 120 mm, when the radius of rotation is 70 mm and the equilibrium speed is 380 rpm, find the free length of the spring. If the radius of rotation increases to 120 mm, what will be the corresponding percentage increase in speed? Ignore sleeve mass. 25

3. (a) A V-belt of 6.0 cm^2 crass-section has a groove angle of 40° and an angle of lap of 150°, $\mu = 0.1$. The mass of belt per meter run is 1.2 kg. The maximum allowable stress in the belt is 850 N/cm^2. Calculate the horse power that can be transmitted at a belt speed of 30 m/s. 20

(b) A solid right cone of axial length h is made of a material having density ρ and elasticity modulus E. It is suspended from its circular base. Determine its elongation under its own weight. 20

4. (a) The pressure within the cylinder of a hydraulic press is 9 MPa. The inside diameter of the cylinder is 25 mm. Determine the thickness of the cylinder wall, if the permissible tensible stress is 18 N/mm^2. 10

(b) A mild steel shaft has to transmit 100 hp at 200 rpm. Design a cast iron flange coupling for the shaft. The allowable stresses are as follows:
Shear stress for shaft and key = 40 N/mm^2
Shear stress for bolts = 28 N/mm^2
Shear stress for C.I. coupling = 20 N/mm^2
Take bearing stress as twice the shear stress value and number of bolts for the coupling as 6.
Sketch the Coupling showing various dimensions. 30

SECTION—C

5. (a) Discuss the effect of Manganese and Nickel as alloying elements in steels and cast irons. 8

(b) Distinguish between (i) Pearlite and Martensite transformation (ii) White and Nodular cast iron. 16

(c) Write a FORTRAN program to read in the elements of the n × m matrix A and also that of the m × n matrix B, and then perform the matrix multiplication operation C = AB. 16

6. (a) Describe Thermit Welding and mention its applications. 10

(b) A cylindrical block of diameter d_0 and height h_0 is forged to a disc of diameter d and height h in an open die forging operation.
Determine
(i) the final disc diameter, d
(ii) the true strain in the longitudinal direction ε_h

(iii) show also that the true longitudinal strain, ε_h is twice the true radial strain, ε_t. 15

(c) What is a DNC system in manufacturing? What are its basic components? 15

7. (a) Workers come to tool store room to enquire about special tools needed in a particular project. The average time between two arrivals is 40 sees and the arrivals are assumed to be in Poisson distribution. The average time of the tool room attendant is 30 sees. Determine

(i) average queue length
(ii) average length of non-empty queues
(iii) average number of workers in system including the worker being attended
(iv) mean waiting time of an arrival
(v) average waiting time of an arrival, who waits
(vi) whether additional number of tool store room attendants is needed to minimize the combined cost of attendant's idle time and the cost of workers' time.

Assume the charges of a skilled worker Rs. 15 per hour and that of tool store room attendant Rs. 4 per hour and also 8working hours a day. 24

(b) Write short notes on (i) Dynamic Programming (ii) Product Planning. 16