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) A Piston-cylinder device contains 3 kg of wet steam at 1.4 bars. The initial volume is 2.25 m^3. The steam is heated until its temperature reaches 400°C. The piston is free to move up or down unless it reaches the stops at the top. When the piston is up against the stops the cylinder volume is 4.65 m^3. Determine the amounts of work and heat transfer to or from steam. 20

(b) An evacuated bottle of 0.5 m^3 volume is slowly filled from atmospheric air at 1.0135 bars until the pressure inside the bottle also becomes 1.0135 bars. Due to heat transfer, the temperature of air inside the bottle after filling is equal to the atmospheric air temperature. Determine the amount of heat transfer. 20

2. (a) Two blocks of metal, each of mass M and specific heat C, initially at absolute temperatures T_1 and T_2 respectively, are brought to the same final temperature by means of a reversible process. Derive an expression for the amount of work obtained during the process in terms of M, C, T_1 and T_2.

(b) In a residential heat pump system the refrigerant flow rate is 412.2 kg/hr and the electric energy supplied to the compressor is 25,480 kJ/hr. The properties of the refrigerant at the inlet (state 1) and at exit (state 2) of the compressor are as given below:

State	T(°C)	P(bars)	h(kJ/kg)	s(kJ/kg K)
1	−1	2.6	226.35	0.8636
2	93	15.0	286.40	0.9222

Determine the amount of available energy destroyed in the compressor in kJ/hr. All heat transfer, if it occurs, takes places at T_0. Assume $T_0 = 273$ K, $P_0 = 1$ atm. 20

3. (a) In an air-standard Brayton cycle the minimum and maximum temperatures are 300 K and 1200 K, respectively. The pressure ratio is that which maximizes the network developed by the cycle per unit mass of air flow. Calculate the compressor and turbine work, each in kJ/kg air, and the thermal efficiency of the cycle. 20

(b) Octane, C_gH_{ig}, is burned with dry air. The molar analysis of the dry products is $CO_2 = 10\%$; $CO = 0.4\%$; $O_2 = 3\%$ and $N_2 = 86.6\%$. Determine the air fuel ratio on a mass basis and the dew point temperature of the products if the products are at 1 atm. pressure. Dry air contains 3.76 moles of nitrogen per mole of oxygen. 20

4. (a) A single stage steam turbine is supplied with steam at 5 bars, 200°C at the rate

of 50 kg/min. It exhausts into a condenser at a pressure of 0.2 bars, the blade speed is 400 m/s. The nozzles are inclined at an angle of 20° to the plane of the wheel and the outlet blade angle is 30°. Neglecting friction losses, determine the blade efficiency, the stage efficiency and the power developed by the turbine. 20

(b) What is a shock wave? Write the continuity, momentum and energy equations relating points 1 and 2, just upstream and just downstream, respectively, of a normal shock in a constant area duct. State whether the following properties of the flow stream increase, decrease or remain unchanged across a normal shock: total pressure, total energy, static temperature, density and velocity. 20

5. (a) A cascade refrigeration system of 100 tons (350 kW) capacity uses ammonia and carbon dioxide, the evaporating and condensing temperatures of CO_2 are –40°C and 5°C, respectively. The evaporating temperature of NH_3 is –7°C. The power supplied to the ammonia compressor is 96.5 kW. In the CO_2 circuit, the liquid leaving the condenser is saturated, the vapor leaving the evaporator is dry and saturated, and compression is isentropic. Calculate the mass flow rate of CO_2 and the C.O.P. of the system.

The following data for CO_2 may be used:

Temperature	Pressure	Enthalpy kJ/kg		Entropy, kJ/kg K	
°C	bars	Liquid	Vapor	Liquid	Vapor
–40	10.05	332.7	652.8	3.8531	5.2262
5	39.70	431.0	649.8	4.2231	5.0097

Specific heat of superheated vapor C_P = 0.85 kJ/kg K. 20

(b) Sketch curves showing the variation of pressure ratio (or head) versus volume flow rate for the three types of blades generally used in centrifugal compressors. Indicate on each curve the stable range of operation. Show that the stage efficiency η_S and overall efficiency η_C of an axial flow compressor are related by

$$\eta_C = \frac{\left(P_2/P_1\right)^{\frac{\gamma-1}{\gamma}} - 1}{\left[\frac{\left(P_2/P_1\right)^{\frac{\gamma-1}{n\gamma}} + 1}{\eta_S}\right]^n - 1}$$

where P_1 and P_2 are the total pressures at compressor inlet and exit, respectively, and n is the number of stages. 20

6. (a) A cylindrical tank with hemispherical ends is used store liquid oxygen at –183° C. The diameter of the tank is 1.5m and the total length is 8m. The tank is covered with a 10 cm thick layer of insulation. Determine the thermal conductivity of the insulation so that the boil-off rate does not exceed 10.8 kg/hr. The latent heat of vaporization of liquid oxygen is 214kJ/kg. Assume that the outer surface temperature of the insulation is 27°C and that the thermal resistance of the wall of the tank is negligible. 20

(b) Explain the meaning of the terms "geometric factor" in relation to heat exchange by radiation. Derive an expression for the geometric factor F_{11} for the inside surface of a black hemispherical cavity of radius R with respect to itself. 20

7. (a) In a double pipe heat exchanger, m_hC_h = 0.5 MCCC, m denotes mass flow rate (kg/s), C denotes specific heat (J/kg K),and suffix h and suffix c denote hot and cold fluid, respectively. The hot and cold fluids enter the heat exchanger at temperatures T_{h1} and T_{c1} respectively. Deduce an expression, in terms of T_{h1}, T_{c1} and T_{h2}, for the ratio of the area of a counter-flow exchanger to that of a parallel flow exchanger which will give the same hot fluid outlet temperature T_{h2}. What is this ratio if T_{h1} = 150°C, T_{c1}= 30°C and T_{h2} = 90°C? 20

(b) A spark-ignition engine, designed to run on octane (C_8H_{18}) fuel, is operated on

methane (CH_4). Estimate the ratio of the power output of the engine with methane fuel to that with octane. In both cases the fuel-air ratio is stoichiometric, the mixture is supplied to the engine at the same conditions, the engine runs at the same speed, and has the same volumetric and thermal efficiencies. The heating value of methane is 50,150/kJ/kg while that of octane is 44,880kJ/kg. 20

8. (a) An inward flow reaction turbine, operating under 30m head, develops 4000 kW while running at 300 RPM the overall efficiency of the water turbine is 0.85; the hydraulic efficiency is 0.9; and the radial velocity of flow at inlet is 7 m/s. The inlet guide vane angle at full gate opening is 30°. Calculate the diameter and width of the runner at inlet. Blade thickness coefficient is 5%. 20

(b) The plunger area of a fuel injection pump is 1.6 cm^2 and the plunger velocity is 0.02 cm/degree. The pump runs at 750 RPM. The density of the fuel is 850 kg/m^3 and its viscosity is 0.12 g/cms. If the nozzle orifice area is 0.005 cm^2 and the orifice coefficient of discharge is 0.9, determine the fuel line pressure. The cylinder pressure is 30 bars. Neglect compressibility of the fuel. Determine also the critical fuel line velocity and critical fuel line diameter. 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.

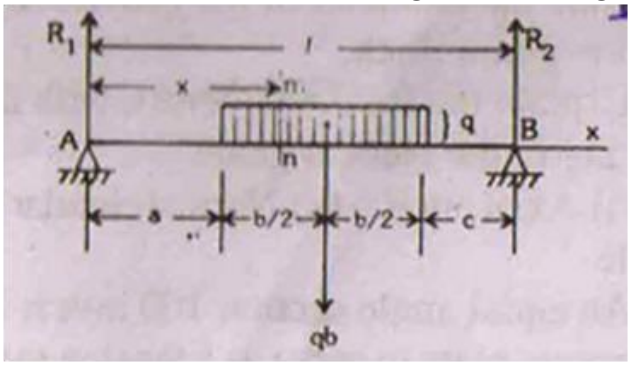
SECTION—A

1. Answer all 20 parts of the question each part carries 2 marks.

(a) Give Klein's construction and its use.
(b) What is the phenomenon of creep in belt drives?
(c) Why is the pressure angle for involute gears always constant?
(d) What is a friction circle? What is the magnitude of its radius?
(e) Differentiate between eutectic and eutectoid.
(f) Distinguish between chaplets and internal chills. What is common between both?
(g) Distinguish between permeability and porosity.
(h) Distinguish between hot and cold chamber die casting machine.
(i) Distinguish between carbonitriding and cyaniding.
(j) What is the method of mass production of toothpaste tubes metallic?
(k) What are therbhgs?
(l) Distinguish between blank holder and ejector pins.
(m) Give two functions of a coolant.
(n) Distinguish between flank wear and crater wear of a single point cutting tool.
(o) Define Poisson's ratio. What is its value for Isotropic materials?
(p) What is creep?
(q) What is event slack time?
(r) Distinguish between thermoplastics and thermosetting plastics.
(s) What is break even analysis?
(t) Expand the abbreviations, (i) EOQ (ii) EDM.

SECTION—B

2. (a) In fig.1 a uniform load q' covers only a part of the span. Calculate the reactions R_1 and R_2 and draw the shear force and bending moment diagrams. 20



(b) What are lame equations?
For a long hollow thick walled cylinder subjected to a high internal pressure,

determine the radial and circumferential stresses throughout the vessel in terms of internal pressure 'p' and internal external radii. 20

3. (a) In the Proel governor shown in Fig. 2 each ball weighs 3 kg and the central sleeve weight is 25 kg. The arms are of 20 cm length and pivoted about axes displaced from the central axis of rotation by 37.5 mm, y = 238 mm, x = 303.5 mm, CE = 85 mm, MD = 142.5 mm. Determine the equilibrium speed. 20

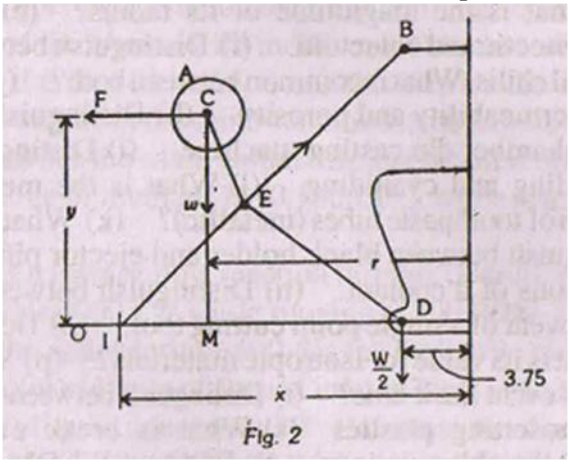


Fig. 2

(b) A prime mover running at 300 rpm, drives a DC generator at 500 rpm by a belt drive. Diameter of the pulley on the output shaft of the prime mover is 600 mm. Assuming a slip of 3 percent, determine the diameter of the generator pulley if the belt running over it is 6 mm thick. 20

4. (a) Explain the following terms, with the help of a neat sketch, pertaining to the Helical gears.
(i) Axial pitch (ii) Normal circular pitch (iii) Lead (iv) Helix angle 20

(b) An equal angle section 100 mm × 100 mm × 8 mm is welded to a gusset plate to serve as a tension member. Calculate the minimum amount of overlapping by the angle section on the gusset plate with a view to limit the induced stress to 100 mega pascal in the angle section when only the side welds are used. The effective area of angle may be taken as the area of the connected leg plus half the area of the unconnected leg. The safe stress in the weld is 90 mega pascal and the shock factor is 1.5. 20

SECTION—C

5. (a) What are the constituents and lattice structure of a steel with 0.2% carbon as it goes from a molten to a solid state. 10

(b) "Moulding sand is different from the river sand." Give your comments in support of the above statement and also indicate the properties of moulding sand which are desirable for making sound castings. How do you determine four of these properties in the laboratory? 20

(c) For manual arc welding of mild steel, what characteristics of current and voltage will be desired? Will the requirements change if we switch over to automatic welding? 10

6. (a) What are the advantages of forging over castings?
How will you mass produce a steel bolt with a hexagonal head? 10

(b) Explain with the help of a sketch the variation of punch pressure with the punch travel for a blanking operation with proper clearance between punch and die.
Why is shear provided on a punch? 10

(c) Distinguish between orthogonal and oblique cutting.
Derive an expression for the shear plane angle in a turning operation on a lathe.
Explain all the assumptions made to arrive at the solution. 20

7. (a) It is a problem for a seed packager to minimize the cost of satisfying the nutritional requirements. Unlimited quantities of seeds can be purchased at the costs indicated below.

Nutritional Item	Proportional Content		Total Requirement
	Buck Wheat	Sunflower Wheat	
Fat	0.04	0.06	$\geq$ 480 kg.
Protein	0.12	0.10	$\geq$ 1200 kg.
Roughage	0.10	0.15	$\leq$1500 kg.
Cost per kg.	Rs.18	Rs.10	

Find the Optimal solution. 20

(b) If Kelvinator produces refrigerator in batches, how many nits in a batch should they produce? In each batch once the production starts they can make 80 units per day. The demand during the production period is 60 units per day. Estimated demand for the year is 10,000 units. Set up cost of the manufacturing process is Rs. 3000/unit. Carrying cost is Rs. 15 per unit per year. 20