**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 insulated tank of 1 $m^3$ volume contains air at 0.1 MPa and 300 K. The tank is connected to a high pressure line in which air at 1 MPa and 600 K flows. The tank is quickly filled with air by opening the valve between the tank and high pressure line. If the final pressure of air in the tank is 1 MPa, determine the mass of air which enters the tank and the entropy change associated with filling process.
Take Universal Gas Constant R = 8.314 kJ/kg-mol-k. 20

(b) By using Maxwell's relations of thermodynamics, show that Joule - Thomson coefficient, μ of gas can be expressed as, 10

$$\mu = \left(\frac{\partial T}{\partial P}\right)_h = \frac{T^2}{C_p}\left[\frac{\partial}{\partial T}\left(\frac{v}{T}\right)\right]_p$$

(c) A heat driven refrigeration system absorbs heat from low temperature TE and rejects it to temperature $T_C$. This is run by heat supplied from a high temperature source at temperature $T_H$, $T_H > T_C > T_E$. Using first and second laws of thermodynamics derive the expression for maximum COP of refrigeration system in terms of temperature. 10

**2.** (a) An automobile carburetor having its float chamber vented to the atmosphere is tested at sea level conditions in the factory without an air cleaner. The main metering system of this carburetor is found yield a fuel-air ratio of 0.065. The venture throat pressure is 0.84 bar. This carburetor is now installed in an automobile and air cleaner is placed on the inlet to carburetor. The air flow rate with and without the air filter is 230 kg/hr. The pressure drop through the filter is found to be 0.035 bar at sea level conditions. Assuming z = 0 and orifice coefficient to be constant calculate
(i) the venturi throat pressure with the air cleaner
(ii) fuel-air ratio with the air cleaner.
Assume incompressible flow. 15

(b) Explain the working of a representative Nuclear Power plant with a suitable diagram. List the various nuclear fuels that can be used. 15

(c) Explain the working principle of a Turbo-Jet engine with a suitable figure. 10

**3.** (a) A circular pipe of radius $r_0$ is being lagged with insulation of thermal conductivity k. If convective heat transfer coefficient is h, derive the expression for critical insulation thickness. 5

(b) Air with an average velocity of 10 m/s at 300 K enters a copper tube of 11.2 mm diameter and 2.5 m length. The tube wall is maintained at 373 K by condensing

steam at atmospheric pressure. Using LMID method, determine the temperature of air at outlet of tube.

Average properties of air are k = 0.02624 W/m-k, $C_p$ = 1.005 kJ/kg-k, $\rho$ = 1.174 kg/m$^3$, $\nu = 1.568 \times 10^{-5}$ m$^2$/s, Pr = 0.7.

$$Nu = 3.66 + \frac{0.668(d/L)\,\mathrm{Re.Pr}}{1 + 0.4(d.\mathrm{Re.Pr})} \quad \mathrm{Re} < 2300$$

$$Nu = 0.023\,\mathrm{Re}^{0.8}.\mathrm{Pr}^{0.4} \quad \mathrm{Re} > 2300$$

where, d and L are diameter and length of tube respectively.

Assume heat transfer coefficient to be constant and neglect conduction thermal resistance of copper. 20

(c) The cross-section of a very long black body enclosure consists of a semicircle with its diameter D as base. The temperature of semi-circle is 1000 K and that of diameter is 500 K.

Determine the shape factors for diameter-semicircle combination and the radiation heat transfer rate. Per unit width (in terms of D)

Stephan-Boltzman constant = $5.64 \times 10^{-8}$ W/m$^2$-K. 15

**4.** (a) If gas is used as refrigerant in Reverse Carnot refrigeration cycle, Draw T-s and p-v diagrams with heat rejection and heat absorption temperature of $T_E$ and $T_C$ respectively. Show that this cycle requires two compressors and two expanders. Find their work requirement and the COP of the cycle. 10

(b) Dense air is used as refrigerant in Reverse-Brayton or Bell-Coleman or Joule cycle. Draw T-s and p-v diagrams for the cycle. Derive the expression for COP in terms of pressure ratio. If temperatures at the end of heat absorption and heat rejection are 0 °C and 30 °C respectively, the pressure ratio is 4 and the pressure in the cooler is 4 bar, determine the temperatures al all state points and volume flow rates at inlet to compressor and at exit of turbine for 1 TR cooling capacity. 15

(c) In an air-conditioned space, 50 kga/s of fresh air at 45'IV C dry-bulb temperature and 30% relative humidity is introduced. The room air at 25°C dry-bulb temperature and 50% relative humidity is recirculated at 450 kga/s. The mixed air flows over a cooling coil which has apparatus dew point of 12°C and bypass factor of 0.15. Determine the conditions at outlet of cooling coil, RSH, RLH, the cooling load of coil and the condensate rate.

The saturation pressure of water at required temperatures are

| t°C | pws (bar) |
|---|---|
| 12 | 0.014016 |
| 25 | 0.03166 |
| 45 | 0.09584 |

$$h = 1.005\,t + W\,(2500 + 1.88\,t)\ \mathrm{kJ/kga}$$

t is in °C and kga refers to kg of dry air. 15

**5.** (a) Describe the working principle of a Pitot-static tube with the help of a neat sketch and explain how it can be used to measure the flow rate? 10

(b) Determine the throat diameter of a venturi-meter in an installation of 100 mm diameter pipe carrying water. The maximum range available in water-Hg differential pressure gauge is 50 cm of Hg deflection. Find the maximum throat diameter which will induce full gauge deflection when the flow rate is 20 l/s. Assume $C_d$ = 0.984. 20

(c) Air at 10 bar and 500 K stagnation conditions flows through a nozzle. The area at the exit of nozzle is $0.25 \times 10^{-4}$ m$^2$. The pressure at exit is 2 bar. Determine the velocity, specific volume and mean flow rate through the nozzle. 10

**6.** (a) Considering isentropic flow in a nozzle show that

$$\frac{P^*}{P_0} = \left\{\frac{2}{\gamma+1}\right\}^{\frac{\gamma}{\gamma-1}}, \quad \frac{\rho^*}{\rho_0} = \left\{\frac{2}{\gamma+1}\right\}^{\frac{1}{\gamma-1}}, \quad \frac{T^*}{T_0} = \left\{\frac{2}{\gamma+1}\right\}$$

where * refers to- M = 1 and subscript zero refers to stagnation condition. 8

(b) Derive Darcy-Weisbach equation for head loss in pipe due to friction. 7

(c) A reservoir supplies 45,000 $m^3$ of water in 8 hours. During this time, the level of water in the reservoir drops from 125 m to 75 m. The head loss in the pipeline is 15 m. Determine the diameter of the supply pipeline using $4f = 0.04$ in Darcy-Weisbach equation. 15

(d) Give the expressions for the following dimensionless numbers and highlight their physical significance:
Reynolds Number (Re)
Mach Number (M)
Euler Number (E)
Weber Number (W)
Froude Number (Fr) 10

**7.** (a) Derive the Euler's equation for rotating machines and explain the physical significance of each term. 10

(b) What is the effect of blade outlet angle on the performance of centrifugal compressors? 10

(c) Define the specific speed for turbines stating the approximate range for various types of turbines. What is the physical significance of specific speed? 10

(d) What is meant by cavitation and what are the methods of avoiding it? 5

(e) What is the purpose of draft tube in turbines? 5

**8.** (a) Find the optimum intermediate pressure of a two stage reciprocating compressor if inter-cooling is done up to a temperature $T_\infty$ which is greater than the inlet temperature. 10

(b) Show the Reheat cycle and Regenerative feed water heating cycle on T-s diagram. Highlight their significance on the performance of steam power plant. 5

(c) The following particulars refer to a two row velocity compounded impulse steam turbine (wheel):
Steam velocity at nozzle exit = 600 m/s
Nozzle angle = 16°
Mean Blade Velocity = 120 m/s
Exit angles: first row of moving blades = 18°
fixed guide blade = 22°
second row of moving blades = 36°
Steam flow rate = 5 kg/s
Blade friction coefficient = 0.85
Determine:
(i) the tangential thrust
(ii) the axial thrust
(iii) the power developed and
(iv) the diagram efficiency 25

**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) Why are the bolts, subjected to impact, made longer?

(b) Why are antifriction bearings not used at very high speeds?

(c) If two cantilever beams of identical dimensions but made of mild steel and gray cast iron are subjected to same point load at the free end, within elastic limit, which one will deflect more and why?

(d) Differentiate clearly between 'shaft' and 'axle'.

(e) Which principle reduces the problem of kinetics to equivalent problem of statics?

(f) What is the magnitude of coriolis acceleration for a slider sliding at 10 cm/sec. on a link which is rotating at 60 r.p.m.?

(g) Why sometimes the axis of translating roller follower in a cam-follower mechanism is offset from the axis of cam rotation?

(h) Name the different types of cast irons and mention, which type is the hardest.

(i) Compare die casting with investment casting w.r.t. production rate, melting point of work materials and ability of producing complex shaped products.

(j) Name three processes of manufacturing long low carbon steel tubes.

(k) What are the relative advantages of submerged arc welding over conventional open air manual arc welding and why?

(l) Why are the lathe-spindles made hollow?

(m) How does application of cutting fluid help in reducing cutting forces and improving tool life and surface quality?

(n) In which machine tools, teeth of internal spur gears can be cut and which one of those machine tools work fastest?

(o) What are meant by 'A-60-K-8-V' when used for a grinding wheel specification?

(p) What do you understand by the term anisotropy? State any 3 materials where the anisotropy is an important consideration.

(q) What is the difference in the analysis of thick tubes compared to that for thin tubes? State the basic equations describing stress distribution in a thick tube.

(r) State a generalized quantitate forecast model. What are the possible nature of independent variables when using extrapolation of a time series concept?

(s) State Johnson's rule for scheduling of n jobs requiring two operations on two separate facilities where the sequence cannot be altered.

(t) State Pareto's principle. State some of its applications.

## SECTION—B

**2.** (a) The bearings of a shaft at A and B are 5 m apart. The shaft carries three eccentric masses C, D and E which are 160 kg, 170 kg and 85 kg respectively.

The respective eccentricity of each mass, measured from the axis of rotation is 0.5 cm, 0.3 cm and 0.6 cm, and the distance from A is 1.3 m, 3 m and 4 m respectively. Determine the angular position of each mass with respect to C, so that no dynamic force is exerted at B, and also find the dynamic force at A for this arrangement when the shaft runs at 100 r.p.m. 15

(b) The total sleeve movement in a Hartnell governor is 3 cm. The mass of the rotating balls is 1.5 kg each. At the mid-position of the sleeve, the sleeve arm, which is 6.5 cm long, is horizontal. The ball arm has a length of 7.5 cm. At the mid-position of the sleeve, the balls rotate at a radius of 10.5 cm. Due to maladjustment of the spring, the equilibrium governor speed at the topmost position of the sleeve is 415 r.p.m. and that corresponding to the lowest position is 430 r.p.m.
Determine (i) the stiffness and initial compression of the spring and (ii) the required initial compression of the spring to give an equilibrium speed at the topmost position which is 10 r.p.m. more than that at the lowest position. Neglect the moment due to the weight of the balls. 15

(c) Two standard full depth gears of pressure angle 14 ½ ° have a module of 5 mm. The pinion has 15 teeth while the gear has 60 teeth. If the addendum of the gear is equal to the module-
(i) show that the gear will interfere with the pinion.
(ii) to what value should the pressure angle be increased in order to eliminate the interference? 10

**3.** (a) A pair of straight teeth spur gears having 20° full depth involute teeth is to transmit 20 kW. The pinion runs at 300 r.p.m. and the speed ratio is 3 : 1. The following data are given:
Number of teeth on pinion = 15.
Service factor $C_s = 1$.
Velocity factor $C_v = \frac{3}{3+v}$ where v is the pitch line velocity in m/sec.
Tooth form factor

$$y = 0.154 - \frac{0.912}{T}$$

where T = Number of teeth.
Face width = 14 m where m = module in mm
Allowable static stress for pinion and gear materials are 120 MPa and 100 MPa respectively.
Check the gear for wear if the surface endurance limit is 600 MPa and modulus of elasticity for pinion and gear materials are 200 GPa and 100 GPa respectively. 20

(b) A transmission shaft, rotating at 500 r.p.m., drives a milling machine which requires 3.75 kW at 750 r.p.m. A 300 mm diameter cast iron pulley is mounted on the transmission shaft. A preliminary design proposes using a belt 4.75 mm thick, which has a density of 970 kg/m$^3$. The allowable stress is 2 MPa. Two pulley rotate in opposite directions and the centre distance of the shafts is 750 mm. The coefficient of friction is 0.3 for both the pulleys. Determine the width of the belt. 10

(c) A 5 cm diameter solid shaft is welded to a flat plate by 1 cm fillet weld. What will be the maximum torque that the welded joint can sustain if the permissible shear stress in the weld material is not to exceed 8 kN/cm$^2$? Deduce the expression for the shear stress at the throat from the basic theory. 10

**4.** (a) Derive an expression for the distortion energy per unit volume for a body subjected to a uniform stress state, given by the principal stresses $\sigma_1$ and $\sigma_2$ with the third principal stress $\sigma_3$ being zero. 10

(b) A beam of rectangular cross-section 50 mm wide and 100 mm deep is simply

supported over a span of 1500 mm. It carries a concentrated load of 50 kN, 500 mm from the left support. Calculate -

(i) the maximum tensile stress in the beam and indicate where it occurs;

(ii) the vertical deflection of the beam at a point 500 mm from the right support.

E for the material of the beam = $2 \times 10^5$ MPa. 20

(c) The magnitudes of normal stresses on two mutually perpendicular planes, at a point in an elastic body are 60 MPa compressive and 80 MPa tensile respectively. Find the magnitudes of shearing stresses on these planes if the magnitude of one of the principal stresses is 100 MPa tensile. Find also the magnitude of the other principal stress at this point. 10

**SECTION—C**

**5.** (a) How does a cutting tool fail? 10

(b) List the different methods suitable for making through holes of diameter around 4 mm in a 2 mm thick glass plate. State briefly the working principle of ultrasonic machining (USM). 15

(c) In a drilling operation under a given condition, the tool life was found to decrease from 20 min to 5 min due to increase In drill speed from 200 r.p.m. to 40 r.p.m. What will be the tool life of that drill under the same condition if the drill speed is 300 r.p.m.? 15

**6.** (a) What are the major constituents of high speed steel (HSS) and uncoated single carbides which are used as cutting tool materials? How are those carbide tool inserts manufactured? 10

(b) How much force will be required to pierce a circular hole of diameter 20 mm in a 2 mm thick mild steel plate with the help of flat ended die and punch in a press tool? The shear strength of the work material is 350 MPa. 10

(c) Name the instruments by which diameter of machined circular holes can be measured and mention their application capabilities in terms of precision and diameter range. 10

(d) The thickness of a rectangular brass plate of length $L_w$ and width $B_w$ has to be reduced by t mm in one pass by a helical fluted plain or slab milling cutter of length $L_C$ ($> B_w$), diameter D and number of teeth, $Z_C$ at cutting velocity, $V_C$ m/min and feed, $S_0$ mm/tooth. How will you determine the time that will be required to accomplish the aforesaid work?
All other dimensions are in mm. 10

**7.** (a) A train reservation facility has 5 counters each capable of handling 20 request per hour. The persons coming for reservation arrive at a mean rate of 90/hour. Assume that each person comes with one request only.
Calculate -

(i) the mean number of persons at any time at this facility

(ii) the mean time a person spends at the facility

(iii) the average length of queue at each counter

when (1) the time to serve a request is constant and (2) the time to serve a request is exponentially distributed with the same mean rate i.e. 20/hour. What would happen to the queue if the arrival rate was to reach $10^5$/hour. 25

(b) Why do we need inventory? Explain why we need to optimize the order quantity. The demand for a component is 10000 pieces per year. The cost per item is Rs 50 and the interest cost is 1% per month. The cost associated with placing an order is Rs 240. What is the EOQ? 15