MECHANICAL ENGINEERING- PAPER I

Time allowed: 3hours **Maximum marks: 300**

INSTRUCTIONS

Each question is printed both in Hindi and in English.

Answers must be written in the medium specified in the Admission Certificate issued to you, which must be stated.

It early on the cover of the answer-book in the space provided for the purpose.

No credit will be given for the answers written in a medium other than that specified in the Admission Certificate.

*Candidates should attempt questions **1** and **5** which are compulsory and any **THREE** of the remaining questions electing at least **ONE** question from each Section.*

All questions carry equal marks.

Section A

1. Answer any three of the following: (Each answer should not exceed 200 words):

20 x 3 = 60

(a) Sketch and describe any mechanism which can give an exact, generated straight-line motion. Give mathematical analysis involved.

(b) What is CORIOLIS component of acceleration? Derive an expression for evaluating it and explain how the direction is fixed.

(c) Discuss the effect of primary, secondary forces and couples in a four cylinder in-line four-stroke engine with mathematical analysis. Compare the above engine with three-cylinder in-line engine in respect of balancing.

(d) From first principles derive an expression for the frequency of free damped vibration of a single degree freedom with viscous damping.
Prove that the amplitude of successive oscillations are in geometric progression for the above system.

2. (a) A weight W of 75 kgf is hung from a rope wrapped round a drum of effective radius of 0.3 meter which is keyed to shaft A. Shaft A is geared to shaft B which runs at 6 times the speed of shaft A. The total mass moment of inertia of the masses attached to shaft A is 100 kgf-m^2 and that of shaft B is 5 kgf-m^2. Find the acceleration of weight W, if it is allowed to fall freely. Draw the free body diagram of shaft A. The configuration of the system is shown in Fig. 1.

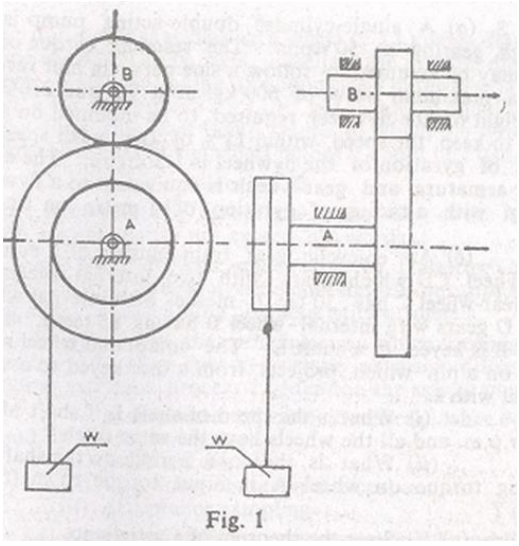


Fig. 1

(b) A thin circular disc is fitted to a shaft as shown in Fig. 2. Weight of the disc is 50 kgf and diameter is 120 cm. Shaft rotates at 300 r.p.m. in anti-clockwise direction when seen from the right side.

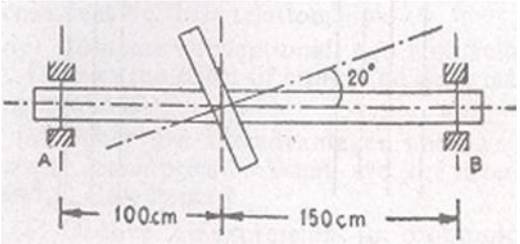


Fig. 2

Find the effect of gyroscopic couple on the shaft and the bearing reactions at A and B taking the effect of weight of the disc.

3. (a) A single-cylinder double-acting pump is driven through gearing at 50 r.p.m. The resisting torque of pump shaft may be assumed to follow a sine curve in half revolution with a maximum value of 600 kgf-m at 90° and 270°. Find the weight of the flywheel required to be mounted on a pump shaft to keep the speed within 1½ % of the mean speed if the radius of gyration of the flywheel is 1.5 meter. The effect of motor armature and gear-wheels is equivalent to a flywheel of 450 kgf with a radius of gyration of 1 meter on the pump shaft.

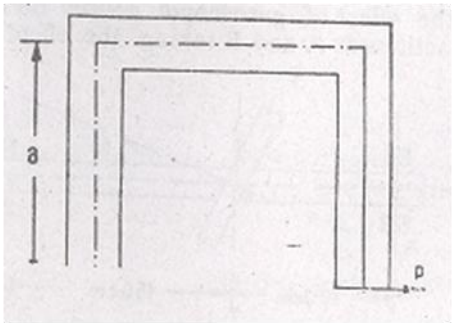
(b) An epicyclic gear train consists of a compound gear-wheel CD which gears with two internal wheels A and B. Gear-wheel C has 30 teeth meshes with internal wheel A, while D gears with internal wheel B having 85 teeth. Internal wheel B is keyed to a shaft L. The compound wheel revolves freely on a pin which projects from a disc keyed to a shaft M coaxial with L.

(i) What is the speed of shaft L if shaft M makes1000 r.p.m. and all the wheels have the same pitch?

(ii) What is the load torque on the shaft L and holding torque on wheel A if input torque to shaft M is 8 kgf-m?

4. (a) (i) State the theorem of Castigliano.

(ii) Using the above theorem find the horizontal displacement along the load line of the frame shown in Fig. 3, considering the deflection due to bending only. The moment of inertia is the same for all sections.



(b) A tyre is shrunk on a wheel of 12 meters diameter. Assuming the wheel to be rigid, calculate the internal diameter of the tyre, if after shrinking, the hoop stress in the tyre is 1,200 kgf/cm^2. α for the tyre is 11.7 x 10^{-8} per °C and E equal 2 x 10^6 kgf/cm^2. Find the least temperature to which the tyre must be heated above that of the wheel before it could be fitted.

Section B

5. Answer briefly and precisely any **three** of the following (Each answer should not exceed 200 words):

(a) What do you understand by the term 'Cutting Tool Geometry'? Mention different single-point tool angles and their effect on machining characteristics of metals.

(b) What are the principles on which forming processes are based? How does hydrostatic extrusion differ from conventional extrusion process? Mention the salient points.

(c) With reference to quality control, what do you understand by the following?—

(i) Standard deviation

(ii) Operating characteristic curves

(iii) Acceptance sampling.

(d) Compare different unconventional machining methods and mention their areas of application.

6. (a) List out the assumptions made in Merchant's theory inorthogonal cutting and draw the force diagram.

(b) Represent graphically some of the typical relationships between speed, feed, depth of cut versus surface roughness while turning mild steel with sintered carbides and critically comment on their relationships.

(c) Compare conventional and high velocity forming methods. Discuss the effect of strain and deformation velocity on forming methods.

7. (a) What are the advantages and disadvantages of having excess inventories? What are the inventory policies for A, B and C class items?

(b) Deduce an expression for economic order quantity and clearly state the assumptions made in the derivation.

(c) The rate of use of a particular raw material from stores is 20 units/year. The cost of placing and receiving an order is Rs. 40. The cost of each unit is Rs. 100. The cost of carrying inventory in per cent per year is 0.16 and it depends on the average stock. Determine the EOQ. If the lead time is 3 months, calculate the reorder point.

8. (a) Show how to formulate the general linear programming problem of optimal decision-making.

(b) A small plant makes two types of aircraft parts. It buys castings that are machined, bored and polished. The shop capacity is shown in the table given: Castings for Part A cost Rs. 4 each; for Part B cost Rs. 9 each; They sell for Rs. 8 and Rs. 18 respectively. The three machines have running costs of Rs 40, Rs. 28 and Rs. 35 per hour. Assuming that any combination of Part A and Part B can be sold, what product mix maximizes the profit?

Capacities	Part A	Part B
Machining capacity	50 per hour	80 per hour
Boring capacity	56 per hour	70 per hour
Polishing capacity	70 per hour	50 per hour

MECHANICAL ENGINEERING- PAPER II

Time allowed: 3 hours **Maximum marks: 300**

INSTRUCTIONS

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Candidates should attempt Questions 1 and 5 which are compulsory and any THREE of the remaining questions selecting at least ONE question from each Section.

The number of marks carried by each question is indicated at the end of the question.

Section A

1. Answer any three of the following. Each part of the question be answered in about 200 words only: **20 x 3 = 60**

(a) Explain how the poor takeoff characteristics of turbojet engines can be improved by thrust augmentation.

(b) Compare the normal pressure and flow capabilities of reciprocating, rotary (positive displacement) and centrifugal compressors and give their relative advantages.

(c) A Pitot tube in a wind tunnel gives a static pressure reading of 407 kgf/cm^2 and stagnation pressure reading of 98 kgf/cm^2. It is suspected that the device used for stagnation temperature measurement is faulty and a temperature of 100°C is recorded. If the acoustic velocity under the conditions is equal to 338 m/s, comment on the functioning of temperature measuring device.

(d) Briefly discuss the advantages and disadvantages of gas turbines over the reciprocating IC engines.

2. (a) A rigid vessel of volume 0.3 m3 contains perfect gas at a pressure of 1 kgf/cm^2. In order to reduce the pressure in the vessel it is connected to an extraction pump. The volume flow rate of the gas leaving the vessel is constant at 0.014 m^3/min. Assuming the temperature of the gas to remain constant, calculate—

(i) Time taken to reduce the pressure in the vessel to 035 kgf/cm^2;

(ii) Magnitude and sense of heat transfer between the vessel and the surroundings during the time.

Derive any formula you use. **30**

(b) 6 kg/s of air at 200°C flowing through a pipe at 100 m/s is mixed adiabatically with 1 kg/s of air at 100°C which is flowing through another pipe at 50 m/s. The resulting mixture flows at a pressure of 4 kgf/cm^2 in a pipe of 10 cm diameter. Determine the temperature and velocity of the mixture.

(Assume that C_p = 0.27 kcal/kg-K and R = 29.2 kg-m/kg/K) **30**

3. (a) A boiler has a volume of 10 m^3 and contains water in liquid and vapour phases at 20 kg/cm^2 pressure. Initially the liquid phase occupies half the volume. Fluid maybe allowed to escape from the boiler by two valves one at the top of the boiler and the other at the bottom. Heat is transferred to the boiler at such a rate that the temperature of the fluid remains constant. Find the amount of heat which must be transferred if

300 kg of fluid are allowed to escape via (i) upper valve (ii) lower valve. It may be assumed that no liquid particles are held in suspension in the vapour. **30**

(b) A multistage gas turbine is to be designed with impulse stages and is to operate with an inlet pressure and temperature of 6 kgf/cm^2 and 900 K respectively. The outlet pressure is 1 kgf/cm^2. The isentropic efficiency of the turbine is likely to be 85%. All stages are to have a nozzle outlet angle of 15°, equal inlet and outlet blade angles, a mean blade speed of 250 m/s and equal inlet and outlet gas velocities. Estimate the number of stages required. Assume C_p = 0.276 kcal/kg-K and γ = 1.333.
Any data not given can be assumed suitably. **30**

4. (a) Calculate the power required for two compressors in an ammonia system that serves a 30 tonne evaporator at –28.9°C. The system uses a direct contact cascade condenser, and the condenser temperature is 37.8°C. The following values for ammonia are available:

(1) Properties of superheated Ammonia

Pressure kgf/cm^2	Entropy kcal/kg-K	Temp °C	Enthalpy kcal/kg
4.13	1.3772	48.9	376.9
14.00	1.27	87.8	386.6
14.00	1.3772	150	426.4

(2) Saturated Ammonia

Saturation Temp °C	Saturation Press kgf/cm^2	Enthalpy kcal/kg hg	Enthalpy kcal/kg h_f	Entropy (Vapour) kcal/kg-K
-28.9	1.22	336	11.9	1.3772
30.56	4.13	345	43.7	1.27
37.8	14.0	351.6	86.2	1.171

If instead of two-stage compression a single-stage is used, calculate the power required. Also compare the COP of one-stage and two-stage systems. **35**

(b) A room 7m x 4m x 4m is occupied by an air-water vapour mixture at 38°C. The atmospheric pressure is 1 kgf/cm^2 and the relative humidity is 70%. Determine the humidity ratio, dew-point, mass of air and the mass of water vapour. If the mixture of air-water vapour is further cooled at constant pressure until the temperature is 10°C, find the amount of water which condensed Assume: R_{air}/R_{vapour} = 0.622 and R_{air} = 29.2 kg-m/kg-K. **25**

Section B

5. Answer any three of the following four parts (answer to each part should not exceed 200 words): **20 x 3 = 60**

(a) (i) Show that for an ideal gas with constant heat capacities, the slope of a P-V curve for a reversible adiabatic process is negative and that it has larger absolute value than the slope of a P-V curve for an isotherm at the same value of P and V.

(ii) A thermometer is inserted in a pipe through which is flowing a steady stream of gas at a temperature T_1 and velocity u_1.Will the indicated temperature be higher than, lower than or same as T_1?

(b) Explain the purpose of using regenerative cycles in a power plant. Outline a method for optimum heater location. How does a reheat-regenerative cycle differ from regenerative cycle? Discuss

(c) (i) Prove that system energy is a property. **10**

(ii) Prove that

$$ds = c_v \frac{dT}{T} + \left(\frac{dP}{dT}\right)_v dv$$

(d) (i) What factors affect the formation of carbon deposits and smoke in gas turbine combustion chamber? Discuss.

(ii) Describe the working principle of a psychrometer.

6. (a) Explain the term 'critical insulation thickness'. A small electric heating application uses 0.183 cm diameter wire with 0.071 cm thick insulation. The thermal conductivity of the insulation is 0.1015 kcal/m-hour °C and surface convection heat transfer coefficient is 29.3 kcal/m^2-hour °C. Calculate the critical thickness of the insulation and the effect of employing critical insulation thickness. Assume that the temperature difference between the surface of the wire and surrounding air remains unchanged. Derive the formula, used. **30**

(b) In a long tube of outer radius r_0 is insulated at its outer periphery. The tube is cooled at the inner radius r_1.Uniform heat generation at the rate of q occurs within the solid walls of the tube.

(i) Find a general solution for temperature distribution in the tube. (The maximum permissible temperature at the insulated surface $r = r_0$ is T_0).

(ii) Heat removal rate.

Assumptions, if any, be stated clearly. **30**

7. (a) For flow of a liquid metal through a circular tube, the velocity and temperature profiles at a particular axial location may be approximated as being uniform and parabolic respectively. What is the value of Nusselt number at this location? **20**

(b) A thermocouple situated at the centre of a circular duct of 10 cm diameter 0.25 m long has a spherical bead of 2 mm diameter. It reads 185°C with gas at 200°C flowing along the duct. The wall of the duct is at 140°C. Assuming that radiation surfaces are black, determine the convective coefficient of heat transfer between the gas and bead. Stephan-Boltzmann constant = 5.663 x 10^{-8} J/m^2s, K^4= 4.9 x $l0^{-8}$Kcal/m^2hrK^4. **10**

(c) The decorative plastic film on a copper sphere of 10 mm diameter is cured in an oven at 75°C. Upon removal from the oven, the sphere is subjected to an air stream at 1 atm and 23°C having a velocity 10 m/s. Estimate how long it will take to cool the sphere to 35°C.

Given:

(i) For copper (at T = 328 K),

ρ = 89.33 kg/m^3, k = 399 W/mK, C_p = 387 J/kg-K

(ii) For air (T_∞ = 296 K),

μ = 18.6x 10^{-7} Ns/m^2, ν =15.36 x $l0^{-6}$ m^2/s, k = 0.0258 W/mK; Pr = 0.709

Air (T_∞ = 328 K), μ = 197.8 X 10^{-7} Ns/m^2;

[ρ = viscosity, ν = kinematic viscosity, k = thermal conductivity] **30**

8. (a) Show by dimensional analysis that for turbulent flow in rough pipes the resistance coefficient f is a function of Reynolds number and the ratio R/k where R is the pipe radius and k is the average height of the roughness projections on the wall of the pipe. **20**

(b) Derive an expression for specific speed of a turbine in terms of its speed N, output power P and head H.

At a hydroelectric station the available head is 60 m and it is anticipated that 32.3 m^2/s of water will be available. Francis turbines of specific speed of 190 are to be installed and are to run at 500 r.p.m. with an overall efficiency of 82%. Determine the maximum power available from the turbines and the number required. **20**

(c) Discuss the various mechanisms of heat transfer that take place when a red hot steel is quenched in a brine solution at atmospheric temperature till the steel attains the temperature of the brine solution. Sketch the same on a heat flux-temperature diagram. **20**