MECHANICAL ENGINEERING PAPER I

Time allowed: 3 hours **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 clearly 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 selecting 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) If the velocity ratio between two gears is to be constant, prove that the contact surfaces must be so shaped that the common normal intersects the line of centers at a fixed point.

(b) Prove that the critical speed of a shaft is numerically equal to the natural frequency of the shaft in transverse vibrations.

(c) Deduce an expression for the couple that is called into play in the case of a wheel rotating with uniform angular velocity in order to maintain a given rate of precession.

(d) Explain what you understand by theories of Failure. Compare any three Failure theories graphically for an element subjected to two mutually perpendicular direct stresses.

2.(a) Two fixed cylinders of 20 cm dia each are located 1.2 meter centre to centre, at an angle of 45° with the horizontal as shown in Fig. 1. A belt passes over them with a 100 kgf weight supported at one end and a force F applied at the other end in the vertically downward direction. The coefficient of friction between the upper cylinder and the belt is 0.3, and that between the lower cylinder and the belt is 0.2. What should be the range of force F applied at the free end that will enable the weight W neither to move up nor down.

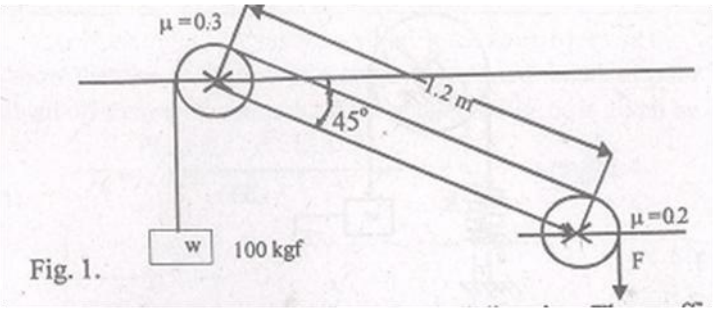


Fig. 1.

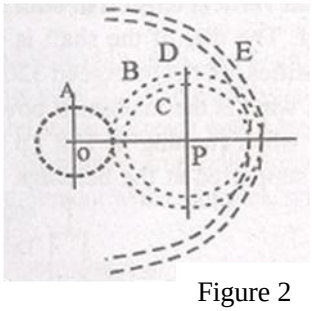
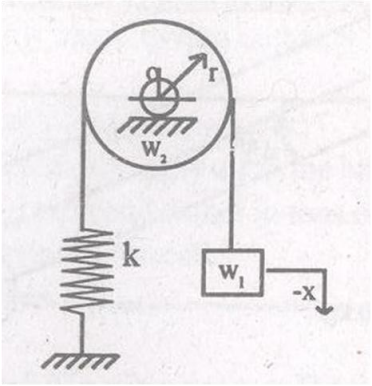


Figure 2

(b) Figure 2 shows diagrammatically a compound epicyclic gear train. Wheels A, D and E are free to rotate independently on spindle O, while B and C are compound and rotate together on spindle P, on the end of arm OP. All the teeth on different wheels have the same module. A has 12 teeth, B has 30 and C has 14 teeth cut externally. Find the number of teeth on wheels D and E which are cut internally.

If the wheel A is driven clockwise at 1 r.p.s. while D is driven counter clockwise at 5 r.p.s, determine the magnitude and direction of the angular velocities of arm OP and wheel E.

3.(a) Determine the natural frequency of the spring pulley-weight system shown in Fig. 3. The weight of pulley is W_2 and its radius is r. It is pivoted about its centre O.



Assume motion of weight W_1 in the direction *x* only. The pulley may be considered to have its radius of gyration equal to its radius *r*. Neglect any slip between the pulley and the string.

(b) Four weights A, B, C and D revolve at equal radii and are equally soaced along a shaft. The weight B weights 7 kgf and the radii of C and D make angles of 90° and 240° respectively with the radius of B. Find the magnitudes of the weights A, C and D and the angular position of A so that the system may be completely balanced.

4.(a) The pulley A excites a torque on the shaft B as shown in Fig. 4. The total vertical tension in both sides of the belt on each pulley is 400 kgf. The dia. of the shaft is 6 cm. If the tensile and shear stress intensities are not to exceed 3200 kgf/cm^2 and 1600 kgf/cm^2 respectively, what is the maximum power that can be transmitted by the shaft when running at 150 r.p.m.? The shaft may be assumed simply supported at the bearings.

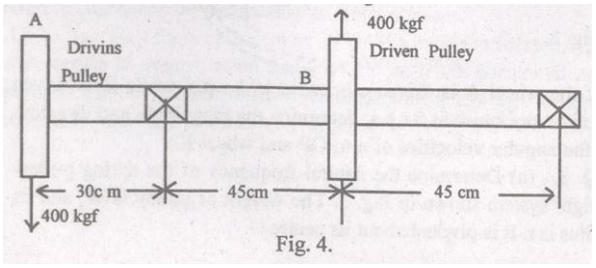


Fig. 4.

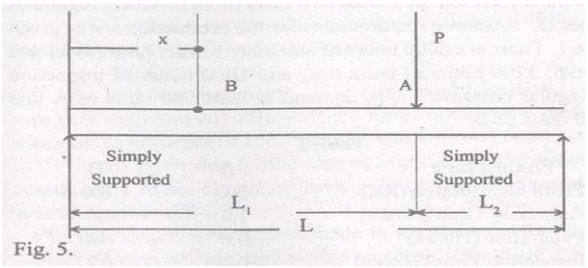


Fig. 5.

(b) Use eight Macauley's method or the Area-Moment method to show that the deflection of a simply supported beam at point B with an off-centre load at point A, as shown in Fig. 5, is given by

$$y_B = \frac{PL_2x(L^2 - x^2 - L_2^2)}{6EIL}$$

Section B

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

20 x 3 = 60

(a) What do you understand by ABC analysis? What is its necessity and what are the steps for the above analysis?

(b) The potion that the work patterns could be studied and improved was the core from which modern production management evolved. Analyse the above statement with examples, with particular reference to work simplification.

(c) Amongst the unconventional machining methods list at least one method falling in each of the following categories:
   (i) Mechanical metal removal processes.
   (ii) Chemical metal removal processes.
   (iii) Thermal metal removal processes.

   Explain briefly the principles of their working and also the areas of their application.

(d) Explain the differences between:
   (i) Hot working and Cold working with their advantages and disadvantages.
   (ii) Drop forging and Press forging processes with reference to the process and products obtained.
   (iii) Impact extrusion and Cold extrusion forging.

6. M/s B.R. & Co. produces two lines of its products regular A and super B. Resource requirements for the production are as given in Table 1. There are 6000 hours of assembly worker hours available per month, 3200 hours of paint time and 1000 hours of inspection time. Regular customers will, demand at least 500 units of A line and 300 units of B.

Table 1

Product Line	A	B
Profit contribution (Rs.)	500	800
Assembly Time (Hours)	1.0	1.4
Paint Time (Hours)	0.6	0.8
Inspection Time (Hours)	0.2	0.2

(a) Formulate an LP model that will determine the optimal product mix on a monthly basis.

(b) Solve the above problem by graphical method. Under the above optimal mix conditions, which shop is the maximum loaded shop and which one is the least loaded-assembly shop, paint shop or inspection floor?

(c) If M/s. B.R. & Co. have to work for prolonged period under the above optimal product mix conditions, what would be your recommendations with regard to reducing worker hours of the most lightly loaded shop, percentage-wise?

7.(a) Describe in detail the steps involved in selecting a sampling plan and for determining the operating characteristics curve for the chosen sampling plan in case of inspection by Attributes.

What information do you get from the OC Curve?

(b) What are the three basic properties of the service facility in a queuing system and what are their characteristics?

(c) What do you understand by Line Balancing? Describe briefly and precisely any one method of Line Balancing.

8.(a) What is the function of a Clamp in tool design? State the requirements of a good clamping system.

With the help of neat sketches describe various clamping devices in common use, their advantages and disadvantages and also their specific use.

(b) Describe briefly and logically the influence of the following variables on the life of a cutting tool:

(i) Cutting speed
(ii) Dimensions of cut
(iii) Tool geometry
(iv) Tool material

In case there are any relationships for estimating the tool life because of the influence of above factors, explain these relations clearly.

(c) Prove that for the case of frictionless wire drawing with plastic rigid material and no back pull, the maximum area reduction is equal to 63%. List the several assumptions made in the above analysis. For a given reduction, how would you decide the value of the semi-die angle α of the conical die.

MECHANICAL ENGINEERING PAPER II

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Section A

1. Answer any three of the following (Answers to each of the parts (a), (b) and (c) should be in about 200 words only): **20 X 3 = 60**

(a) Starting from fundamentals, show that the internal energy of an ideal gas is a function of temperature only.

(b) Write down the momentum and energy equation for the laminar boundary layer on a flat plate in differential from. Give the physical significance of the above equations and the assumptions involved in their derivation.

(c) Discuss, with the aid of a heat flux-temperature plot (on logarithmic scale) the processes taking place when a red-hot steel rod is dipped in brine solution till the steel rod attains the temperature of the brine solution.

(d) Discuss, with illustration, the four factors that make thermodynamic processes irreversible.

2.(a) Derive a relation between the area variation and the Mach number for the flow of reversible, adiabatic, one-dimensional steady flow of an ideal gas through a nozzle. Hence deduce the proper shape for nozzles and diffusers for subsonic and supersonic flows. 40

(b) Derive an expression for the error introduced by assuming incompressible flow when using the Pitot tube to measure the velocity of an ideal gas. 20

3.(a) Starting from fundamentals, show that the reheat and regenerative feed heating improves the thermal efficiency of a simple steam cycle. 20

(b) At a certain instant of time during the process of curing of concrete, the temperature distribution in the concrete is given by

$$T = 0.1 + 0.5x - 0.22x^2$$

where x is the distance in cm from one end. If the thermal conductivity is 0.6 kcal/mhr°C and the density is 2000 kg/m^3 and specific heat is 0.88 kcal/kg°C, determine the rate of cooling of concrete at the instant when the temperature is measured. 20

(c) Saturated steam at 100°C is condensing on the shell side of a shell and tube heat exchanger. The cooling water enters the tubes at 30°C and leaves at 70°C. If the arrangement is (i) parallel flow, (ii) counter flow, calculate the logarithmic mean temperature difference.

Comment on the result. If the flow is cross-flow, what change do you expect in the logarithmic mean temperature difference? What is the significance of the logarithmic mean temperature difference? 20

4.(a) Derive an expression for the critical radius of insulation for a sphere. How does this radius change when the thermal radiation is considered from the insulation surface to the ambient air? 20

(b) A thermocouple used to measure the temperature of a gas stream in a duct records a value of 227°C. If the duct walls are at a temperature of 127°C, calculate the true gas temperature. Assume the participating surfaces are black and the heat transfer coefficient of gas flowing past the thermocouple is 20.5 kcal/m^2hr°C. How can the error be reduced? 20

(c) Distinguish between - 20

(i) Gray surface and Diffuse surface
(ii) Biot number and Nusselt number
(iii) Dropwise and Filmwise condensation
(iv) Radiosity and Emissive power

Section B

5. Answer any three of the following parts (answer to each part should be in about 200 words): **20 X 3 = 60**

(a) How does the combustion phenomenon in C-I engines differ from S-I engines?
(b) Write a note on selection of pumps for various applications.
(c) Discuss the advantages and implementation of MHD Power system.
(d) Compare vapour absorption and vapour compression refrigeration systems.

6.(a) Discuss the phenomenon of stalling and surging in compressors. 20

(b) In a two-row velocity compounded stage for an impulse turbine, the initial speed of steam is 600 m/sec. The speed of blades is 100 m/sec. The nozzles are inclined at an angle of 18°and the discharge angles for the three rows of blades in order are 21½°, 28°and 45°. Assuming frictional loss of speed of 15 percent in each row of blades, find the work done per kg of steam flow and the efficiency of blades. 40

7.(a) In spite of solar energy being available in plenty in India, utilization of solar energy in power sector has not been significant. Discuss the reasons. 20

(b) Show that on a Mollier diagram (h-s diagram) the slope of a constant-pressure line increases with temperature in the superheat region and that the constant-pressure line is straight in the two-phase region. 20

(c) Explain the working of- 20

(i) once through super critical boiler,
(ii) Steam generation by nuclear reactor.

8.(a) Discuss the important properties and characteristics of important refrigerants and the field of application of each one of them. 20

(b) Calculate the power saved by the use of two compressors in an ammonia system which serves a 250 kW evaporator at 25°C. The system uses two-stage compression with inter-cooling and removal of flash gas. The condensing temperature is 35°C. Draw the

process on pressure-enthalpy diagram. How is this system compared with a power cycle with reheating between two stages of expansion in turbines and feed heating? 40
Relevant properties of ammonia are as follows:

Sat.Temp	Pressure	Enthalpy		Entropy		Specific Volume	
°C	kPa	kJ/kg		kJ/kg-K		L/kg	
		h_f	h_g	s_f	s_g	v_f	v_g
-26	145.11	81.53	1428.76	0.546	5.997	1.486	803.761
-24	159.22	90.53	1431.64	0.582	5.965	1.492	736.868
0	430.43	200.000	1461.70	1.000	5.619	1.566	288.88
1	446.76	204.625	1462.76	1.017	5.606	1.569	278.86
2	463.53	209.256	1463.80	1.033	5.592	1.572	269.25
34	1313.9	361.13	1488.13	1.550	5.218	1.697	98.39
35	1352.2	366.072	1488.57	1.566	5.208	1.702	95.63

h at 1352.2 kPa after isentropic compression is 1620 kJ/kg for case of 2^{nd} stage.
h at optimum pressure after isentropic compression is 1573 kJ/kg.
h at 1352 kPa after compression in single stage case is 1765 kJ/kg.