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.
If any data considered insufficient, assume suitable value.
Newton may be converted into kg using the equality 1 kilonewton (1 kN) = 100 kg, if found necessary.

Section A

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

20 x 3 = 60

(a) Obtain the expressions for primary and secondary forces for a V-twin engine having two identical cylinders lying in a plane. The included angle between the cylinder centre lines is 2α.

(b) What is Arnold-Kennedy theorem of three centers? State its importance in kinematic analysis of mechanisms.

(c) What should be the ratio of thickness of a thin cylindrical shell to the thickness of its hemispherical end for a pressure vessel subjected to internal fluid pressure so that the junction section remains free from unequal deformation?

(d) Explain the use of controlling force curves in the determination of stability of a centrifugal governor.

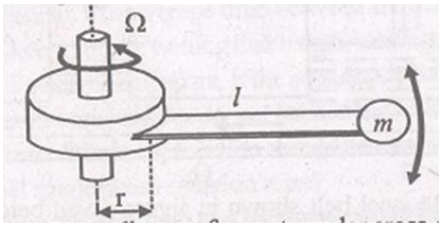
2.(a) Obtain the angle of twist of one end relative to the other of a tapered shall having radii r_1 and r_2 at its ends and of length l. The shaft is subjected to equal and opposite torque T at its ends. Modulus of rigidity of the shaft material is G.

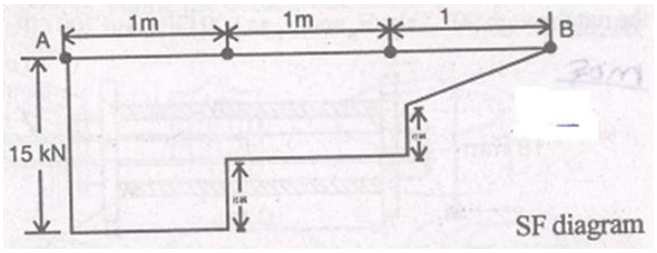
(b) A steel rotor disc of uniform thickness 50 mm has an outside diameter 800 mm and a central hole of diameter 150 mm. There are 200 blades each of weight 2 N at an effective radius of 420 mm pitched evenly around the outer periphery of the disc. Determine the maximum rotational speed such that maximum shearing stress in the disc does not exceed 375 MN/m^2. Take density (ρ) of the steel as 7470 kg/m^3. Following basic relation for radial stress (σ_r) and hoop stress (σ_θ) at radius of routing disc at ω rad/sec can be used with usual

$$\sigma_r = A - \frac{B}{r^2} - (3-\gamma)\frac{\rho\omega^2 r^2}{8}$$

$$\sigma_\theta = A + \frac{B}{r^2} - (3-\gamma)\frac{\rho\omega^2 r^2}{8}$$

3.(a) Figure given below shows a rotating cantilever leaf spring with flexural rigidity EI and carrying a mass m at its free end. Neglecting the mass of the spring. Determine the natural frequency of vibration of the system. The angular speed of the shaft is Ω.





(b) The Shear Force diagram for rectangular cross-section beam AB is shown in the figure given below. Width of the beam is 100 mm and depth is 250 mm determine the maximum bending stress in the beam.

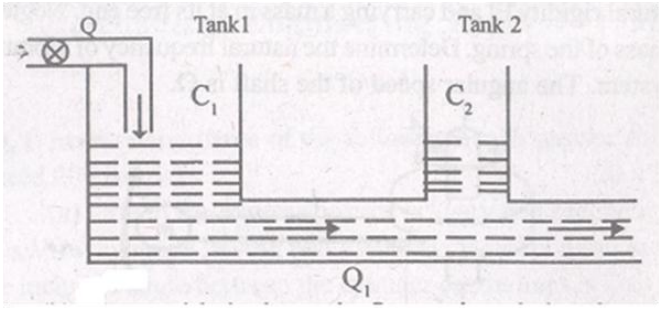
4.(a) A tank having liquid capacitance C_1 is supplying liquid through pipe of resistance R_1 another tank of liquid capacitance C_2 which delivers this liquid through another pipe resistance R_2. The steady-state Outflow rates of tank 1 and that of tank 2 are Q_1 and Q_2 and heads are H_1 and H_2, respectively. The flow balance equation for tank 1 is

$$\Delta Q = \Delta Q_1 + C_1 \frac{d}{dt}(\Delta H_1)$$

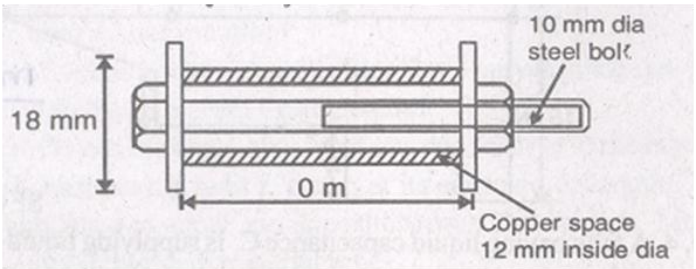
Similarly for tank 2 is

$$\Delta Q = \Delta Q_2 + C_2 \frac{d}{dt}(\Delta H_2)$$

where $\Delta Q_1 = (\Delta H_1 - \Delta H_2)/ R_1$; $\Delta Q_2 = \Delta H_2/ R_2$ and Δ's show small variations of quantities. Draw the overall feedback block diagram of the system and obtain the transfer function.



(b) The steel belt shown in figure given below has a thread pitch of 1.6 mm. If the nut is initially tightened up by hand so as to cause no stress in the copper spacing tube calculate the stress inducted in the tube and in the bolt if a spanner is then used to turn the nut through 90°. Take EC and ES as 100 GPa and 209 GPa respectively.



Section-B

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

(a) How does grain size in a poly crystalline solid affect the strength of the solid? What happens to grain size in (i) forging (ii) rolling.

(b) What is form stability of a culling tool? Discuss the properties required for an ideal cutting tool material.

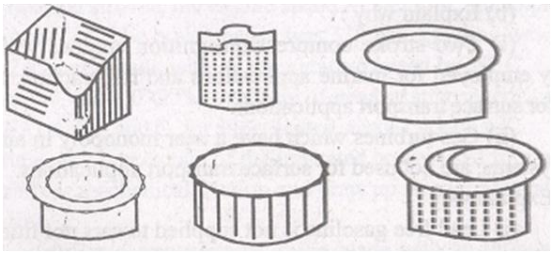
(c) Write complete program in C-language to obtain the output: Civil Services Examination.

(d) Explain with the help of a suitable sketch the working principle of a typical pulsed ruby laser machining system.

6. A factory has a tool crib where mechanic come to check out special tools needed for the completion of a particular task assigned to them. A study is made of the time between arrivals and of the time required for service. Both distributions are found to be adequately described by the negative exponential. The average time between arrivals was found to be 50 seconds. Determine the waiting line length, waiting time and the percent of the idle time of the attendant. If the attendant is paid Rs. 2/- per hour and the mechanics are paid Rs. 4/- per hour, what policy or service should be established? What cost function should be maximized? When will a multi-channel single phase situation arise? 60

7.(a) Determine the workload and frictional power loss for simple forward extrusion with a flat face die. 30

(b) Figure given below illustrates various types of common deep drawing defects. Name the defects and the probable reasons for their development. 30



8.(a) The frictional force f(x) acting on a body is expressed by the following:

$$f(x) = 0 \qquad |x| \leq 0.5$$
$$= 2x^2 \quad for\ x > 0.5$$

This function is required to be used in the following equation:

$$g = \left(\frac{mv}{t}\right) - f(v^2) + at$$

Write a FORTRAN programme for the stated problem. 30

(b) Explain the meaning of cutting tool failure and discuss its modes and causes. 30

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) Prove the validity or otherwise of the following statements
  (i) Availability is a function of stale of the system and the medium and that irreversibility can be evaluated with the help of availability. 10
  (ii) For a perfect gas the work done by a constant pressure expansion from any point on a given isothermal to another given isothermal is constant. 10

(b) Explain why:
  (i) Two stroke compression-ignition engines which are widely employed for marine applications and rail traction, are not used for surface transport applications. 10
  (ii) Gas turbines which have a near monopoly in air transport systems, are not used for surface transport applications. 10

(c) Explain why:
  (i) Lead free gasoline is not supplied to cars not fitted with catalytic convertors in India. 10
  (ii) The exhaust from diesel engine powered vehicles is black in colour with an obnoxious odour while the exhaust coming from petrol engine operated vehicles is not so. 10

(d) (i) Explain briefly the Boundary layer Theory as propounded by Prandtl. 10
  (ii) Obtain an expression for the thickness of the boundary layer for laminar flow assuming the velocity distribution

$$u/U = 2(y/\delta) - (y/\delta)^2$$

where U = approach velocity of the stream, u = velocity of the stream in the boundary layer at a distance y from the boundary and δ = thickness of the boundary layer. 10

2.(a) Discuss the advantages of fuel injection in SI engines over Carburetion. How docs mixture strength affect die concentration of carbon monoxide, hydrocarbons and oxides of nitrogen in SI engine exhaust? 20

(b) A single-cylinder 4-stroke gas engine with a hit and miss governing has 200 mm bore and 400 mm stroke. It recorded a gas consumption of 153 liter/min at 8.75 cm of water

above atmospheric pressure, when barometer reading was 759 mm of mercury, atmospheric and gas temperature was 17 °C. The gas used had gross calorific value of 18200 kJ/m^3 and density 0.592 kg/m^3 both at N.T.P. hydrogen present in the gas was 12 per cent by mass, air consumed was 0.0242 kg/s, for dry exhaust gas was 1.05 kJ/kg K. The mean effective pressure of positive loop was 5.72 and of negative loop 0.274 bar in firing and 0.38 bar in missing strokes, the engine speed as 285 rpm; and explosions per minute 114. The brake torque was 330 Nm. Cooling water used was 9.2 kg per minute with its temperature raised by 20° C. Exhaust temperature was 400 °C. The total heat of steam at atmospheric pressure is 2676 kJ per kg and C_p for superheated steam 1.8 kJ/Kg K.

Calculate the percentage of the indicated power used for pumping work and for mechanical friction and draw up an energy balance for the engine. 40

3.(a) For a free vortex turbine blade with an impulse hub, show that the degree of reaction (R) at any radius (r) is related to huh radius (r_h) by the relation

$$R = 1 - (r_h / r)^2$$ 15

(b) Discuss compressor Stall on the basis of blade angle of attack. 10

(c) In a single stage turbine of free vortex design the inlet total head temperature and pressure are 1000° K and 3.8 kg/cm^2. The static head efficiency is 88 % and nozzle efficiency 96 %. Outlet static pressure is 1.2 kgf/cm^2 and outlet velocity 280 m/sec. If there no outlet swirl and the turbine is designed for impulse conditions at the root radius, find the work output. Also find the nozzle angle and degree of reaction at the tip radius, if the radius ratio of turbine annulus at exit from nozzle is 1.4. Neglecting disc friction and tip leakage loss find nozzle angle and blade angle at root. Assume C_P = 0.276 and γ = 1.333. 35

4.(a) Establish from first principles the Fanno equation and sketch. On T-s plane characteristic "Fanno Line" for a duct of constant cross-section. Mark the subsonic and supersonic parts and the sonic point. 20

(b) Show that in flow through a tube of constant cross-sectional area with heal addition, (i) the Much number at the point of maximum temperature is equal to 1/γ and (ii) the Mach number at the point of maximum entropy is equal to unity. 20

(c) Show that the Mach number behind a normal shock wave may be written in the form

$$M_y = \left(\frac{\gamma+1}{2\gamma}\right) + \frac{P_1}{P_2}\left(\frac{\gamma-1}{2\gamma}\right)^{1/2}$$

where P_1 and P_2 are the pressure before and after the shock wave and γ is the ratio of caloric value. 20

Section-B

5. Answer any three parts out of the following four pans of this compulsory question. Each pan of the question must be answered briefly to the point, in not more than 200 words.

(a) (i) Distinguish between nucleate boiling and film boiling and discuss a typical pool boiling curve. 10

(ii) A drop of oil put on a hot plate dances over the plate before finally evaporating, why? 10

(b) With reference to the refrigeration and air-conditioning practice explain why?

(i) ammonia which is a very good refrigerant, is not used in domestic vapour compression refrigerators. 10

(ii) Hydrocarbons such as propane and butane are being tried as substitutes for Freon refrigerants. 10

(c) (i) Explain with the help of suitable illustrations the phenomena of "Sonic Boom" and "Breaking of Sound Barrier". 10

(ii) Show by dimensional analysis that in forced convection $Nu = \varphi [Re, Pr, U^2/C_PT]$ when friction heating in the fluid cannot be neglected. 10

(d) (i) What is a deacrator, why and where it is used in a thermal power plant? 10

(ii) With reference to an electrostatic Precipitator (ESP), explain the phenomena of Corona discharge and the effect of Sulphur present in fuel on ESP performance. 10

6.(a) Explain how would you find whether a refrigerator is undercharged or overcharged. How would you detect leaking of refrigerant from a refrigerator? Name and describe any equipment/ instrument available for this purpose. 20

(b) A vapour compression ice plant has a twin-cylinder single-acting compressor with a bore and stroke of 90 cm and 70 cm respectively. It works between pressure limits 10.587 bar and 1.826 bar and has mean effective pressure of 334 kN per sq meter. It runs at 500 rev/min, temperature of refrigerant at entry and exit from condenser 65° C and 32° C respectively; rate of flow of cooling water 13 kg per minute with a rise of 8° C and produces at 27° C, 360 kg of ice in 8 hours from water; latent heat of ice is 335 kJ. Find:

(a) the theoretical coefficient of performance

(b) the actual coefficient of performance and

(c) the mass flow of refrigerant per minute

Draw up an energy balance of the plant. The relevant properties of the refrigerant used are:

Pressure	Sat temp.	Enthalpy kJ/kgK		Entropy
bar	C	liquid	Vapour	kJ/kgK
10.587	44	78.679	204.544	0.6814
1.126	-15	22.23	180.973	0.7051

The average specific heat of liquid refrigerant is 1.256 and for superheated vapour it is 0.645 kJ/kg K. 40

7.(a) Distinguish between Black Body Radiation and Grey Body Radiation. Can the displacement law of radiation be applied to Grey Body Radiation? 15

(b) Define Plant's distribution Law and derive Stefan Boltzmann law from Plant's distribution equation. 15

(c) Show that where the heat transfer between two black surfaces is influenced by a third adjoining re-radiating surface in steady state the geometric factor will be given by where F. A have usual meaning and suffix 1. 2, 3 are for the three surfaces respectively.

$$F_{12} = F_{12} + \left[\frac{1}{\frac{A_1}{A_2} + \frac{1}{F_2} + \frac{1}{F_{13}}}\right]$$

30

8.(a) The volumetric percentages of CO2, CO and O2 in the dry flue gas from a boiler using fuel containing C per cent of carbon are X, Y and Z respectively. Show that the quantity of excess air R per kg of fuel burnt can be expressed in the form

$$R = K\frac{CZ}{(X+Y)}$$

Determine the value of the numerical constant K. 20

(b) A boiler with economizer uses coal having the following gravi-metric composition: C = 84%; H_2 = 45%; O_2 = 35%, Moisture = 1% Ash = 7%. The percentage volumetric composition of the flue gas when entering and leaving the economizer was found to be

	CO_2	CO	O_2	N_2
Entering	8.23	0.42	11.40	79.90
Leaving	6.95	0.35	12.95	79.75

Determine per 100 kg of fuel fired:

(a) the mass of the flue gas (including moisture) entering the economizer:

(b) the leakage of air into the economizer;

(c) the loss of heat due to imperfect combustion.

Calorific value of carbon when burnt to CO_2 is 8100 kcal/kg and when burnt to CO is 2430 kcal/kg. Air contains 23 per cent by weight of O_2. 40