14ME702

Hall Ticket Number:

IV/IV B.Tech (Regular/Supplementary) DEGREE EXAMINATION

January, 2021 **Mechanical Engineering**

Seventh Semester **Design of Machine Elements-III**

Time: Three Hours **Maximum :** 60 Marks

Answer ALL Questions from PART-A. (1x12 = 12 Marks)

*Answer **ANY FOUR** questions from PART-B.* (4x12=48 Marks)

Part - A

1 Answer all questions (1x12=12 Marks)

a) What is Wahl's factor? State its importance in the design of helical springs.
b) Define spring rate and spring index.
c) Name the materials used for making leaves of multi-leaf spring?
d) Why heat dissipation is necessary in clutches?
e) Distinguish the clutch and the brake.
f) What is a self-energizing brake?
g) What is the function of flywheel?
h) Define coefficient of fluctuation of energy
i) List various types of stresses induced in flywheel rim.
j) Name the materials used for I.C. engine piston.
k) State the main advantage of overhung crankshaft.
l) What do you mean by Multivariable Optimization?

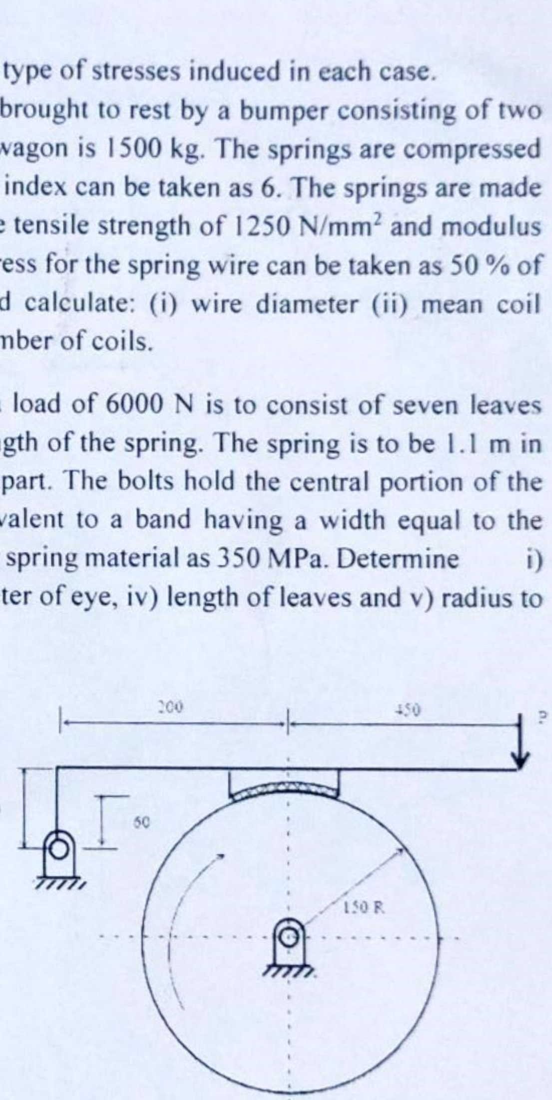
Part - B

2 a) Classify springs according to their shape and explain type of stresses induced in each case. 4M

b) A railway wagon moving at a velocity of 1.5 m/s is brought to rest by a bumper consisting of two helical springs arranged in parallel. The mass of the wagon is 1500 kg. The springs are compressed by 150 mm in bringing the wagon to rest. The spring index can be taken as 6. The springs are made of oil hardened and tempered steel wire with ultimate tensile strength of 1250 N/mm^2 and modulus of rigidity of 81370 N/mm^2. The permissible shear stress for the spring wire can be taken as 50 % of the ultimate tensile strength. Design the spring and calculate: (i) wire diameter (ii) mean coil diameter (iii) number of active coils and (iv) total number of coils. 8M

3 A semi elliptical laminated vehicle spring to carry a load of 6000 N is to consist of seven leaves 65 mm wide, two of the leaves extending the full length of the spring. The spring is to be 1.1 m in length and attached to axle by two U-bolts 80 mm apart. The bolts hold the central portion of the spring so rigidly that they may be considered equivalent to a band having a width equal to the distance between the bolts. Assume a design stress for spring material as 350 MPa. Determine i) thickness of leaves, ii) deflection of spring, iii) diameter of eye, iv) length of leaves and v) radius to which leaves should be initially bent. 12M

4 A single block brake with a torque capacity of 15 N-m is shown in the figure. The coefficient of friction is 0.3 and the maximum pressure on the brake lining is 1 N/mm^2. The width of the block is equal to its length. Calculate (i) the actuating force P to be applied at the end of the lever for the clockwise and anti-clockwise rotation of brake drum (ii) the location of the pivot or fulcrum to make the brake self-locking for the clockwise rotation fulcrum (iii) the dimensions of the block. All dimensions are in mm. 12M



P.T.O.

5 a) Name the different types of clutches. Give at least one practical application of each. 4M

b) A single plate clutch consists of one pair of contacting surfaces. The inner and outer diameters of the friction disk are 125 and 250 mm respectively. The coefficient of friction is 0.25 and the total axial force is 15 kN. Calculate the power transmitting capacity of the clutch at 500 rpm using i) uniform wear theory and ii) uniform pressure theory. 8M

6 The turning moment diagram of a multi-cylinder engine is drawn with a scale of 1mm=10 on abscissa and 1 mm= 250 N-m on the ordinate. The intercepted areas between the torque developed by the engine and mean resisting torque of the machine, taken in order from one end are -350, +800, -600, +900, -550, +450 and -650 mm2. The engine is running at a mean speed of 750 rpm and co-efficient of fluctuation of speed is 0.02. A rimmed flywheel made of Grey cast Iron mass density 7100 kg/m3 is provided. The spokes, hub and shaft are assumed to contribute 10% of the required moment of Inertia. The rim has rectangular cross section and ratio of width to thickness is 1.5. Determine the dimensions of Rim 12M

7 Design and draw a cast iron flywheel used for a four stroke I.C. engine developing 180 kW at 240 rpm. The centrifugal stress developed in the flywheel is 5.2 MPa, the total fluctuation of speed is to be limited to 3% of the mean speed. The work done during power stroke is 1/3 more than the average work done during the whole cycle. The maximum torque on the shaft is twice the mean torque. The density of cast iron is 7220 kg/m^3. 12M

8 Design a Cast Iron piston for single acting four stroke engine from the following data: Cylinder bore = 100 mm, Speed = 2000 rpm, stroke = 120 mm, Maximum gas pressure = 4 N/mm^2, Indicated Mean effective pressure = 0.75 N/mm^2, fuel consumption = 0.15 kg/brake power/hr, High calorific value of the fuel = 42x10^3 kJ/kg, Mechanical efficiency of the engine as 80%. Assume any other data required for the design. 12M

9 a) What are the necessary and sufficient conditions for a multivariable optimization problem? Explain the significance of these conditions in optimization problem. 6M

b) Explain interval halving method and golden section method in brief? 6M

Scheme – 14ME702

part – A

1

(a) $K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$

Am wahl derived equation for resultant stress, which includes torsional shear stress, direct shear stress and stress concentration.

(b) $K = P/\delta$. rate of spring

Spring index $C = D/d$.

(c) Carbon steel, chromimum vanadium steep Nickel- Molybdenum steel, Silicon manganese steel.

(d) To cool the system. To protect from high temperature

(e) Brake is used to stop or decelerate the speed clucth is to used to engage and disenage of Engine and Gear box.

(f) No external force is needed to apply brake $P = 0$

(g) Flywheel is used to minimize the energy fluctuation during cycle of operations.

(h) co-efficient of fluctuatia of speed = $\frac{N_2 - N_1}{N}$

(i) Centrifugal stress, Tensile Bending stresses Shrinkage stresses

(j) Cast iron, aluminum alloys aluminum silicon alloys.

(k) It requires only two bearings in either the single or two crank construction

(l) More Than parameter is optimized with Constraints or without Constraints.

2(a) Spring classification.

Helical spring — (a) Compression spring

(b) Extension spring

Leaf spring

Stresses induced in springs — 4M

(a) pure torsional stress

(b) Direct shear stress

(c) Combined Torsional, Direct and Curvature shear stress

(2b). Data: $m = 1500\,kg$ $v = 1.5\,m/s$ $\delta = 150\,mm$. $C = 6$

$S_{ut} = 1250\,N/mm^2$ $G = 81370\,N/mm^2$ $\tau = 0.5\,S_{ut}$

$KE = \frac{1}{2} m v^2 = 1687.5 \times 10^3$ N-mm

$E = 150P$ N-mm.

$P = 11250\,N$

$K = \frac{4C-1}{4C-4} + \frac{0.615}{C} = 1.2525$

— 4M

$d = 18.56$ or $20\,mm$

$D = 120\,mm$

No. of active coils = 13

Total no. of Coils = 13 + 2 = 15 Coils

— 4M.

3)

Given Data:

$W = 3000N$. $n = 7$ $b = 65 mm$

$n_F = 2$, $2L_1 = 1.1 m$

$l = 80 mm$ $\sigma = 350 Mpa$

1. Thickness of leaves

$2L = 2L_1 - l$

$L = 510 mm$.

$$t = \frac{18 WL}{bt^2 (2n_G + 3n_F)}$$

$t = 9 mm$

4M.

2. Deflection of spring

$$\delta = \frac{12 WL^3}{E b t^3 (2n_G + 3n_F)}$$

$\delta = 30 mm$

4M

3. Diameter of the Eye =

load $W = d\, l_1\, P_b$.

$= d \times 65 \times 8 = 520d$.

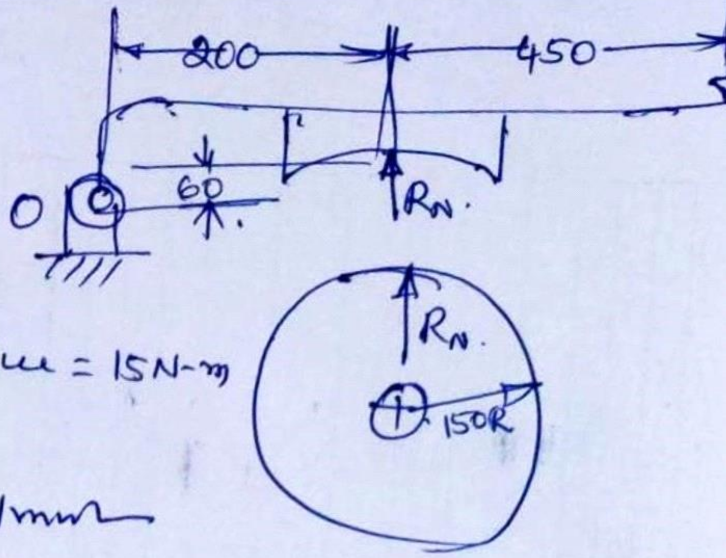
$d = 3000/520$

$d = 5.77$ say $6 mm$

4M.

4.

(4)



Data · ~~P = 6000 N~~ · Torque = 15 N-m
~~wide = 65 mm~~

Stress/pressure = 1 N/mm²
$\mu = 0.3$.

The actuating force
Take the moments about O. (4M)

$P(650) = R_N \times 200$.

$P = 93.33$ N.

Dimensions of block.
pressure = P/Area. 4M.

width = 18.26 mm.
thick = 18.26 mm

Resultant hinge reaction =

R = 260 N.

5(a) Types of clutchs

(a) disc clutch. 1. Single plate
2. multiple plate

4M.

(b) Cone clutch.

(c) Centrifugal clutch

Automobiles.

5(a).

Uniform wear theory

$$P = \frac{2\pi N T}{60}.$$

$$M_t = \frac{\mu P (D+d)}{4}$$

4 m

18.41 kw.

Uniform pressure theory

$$P = \frac{\pi p}{4}(D^2-d^2)$$

~~$M_t = \frac{\mu P}{3}$~~ $\quad kw = \frac{2\pi n M_t}{60 \times 10^6}.$

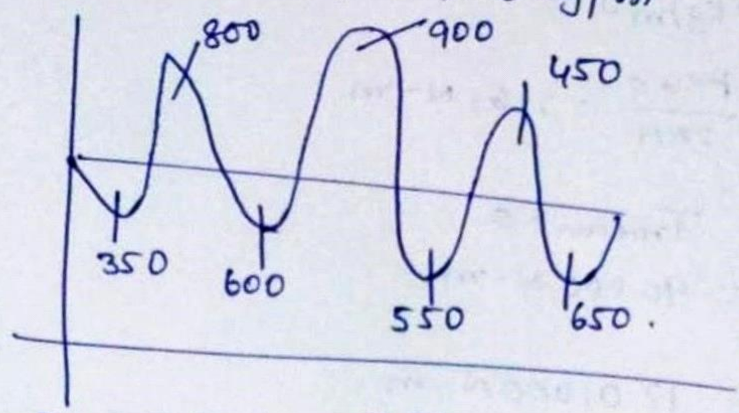
4 m.

Power = 19.09 kw.

(6)

Given: $n = 750$ rpm $\quad C_s = 0.02 \quad b/t = 1.5$

$K = 0.9 \quad \rho = 7100\ kg/m^3$



4M.

$E_B = U - 350 \quad E_F = U + 200$

$E_C = U + 450 \quad E_G = U + 650$

$E_D = U - 150 \quad E_H = U.$

$U_E = U + 750$

$U_0 = 4799.66$ N-m.

(2) Dimensions of rim

$\omega = \frac{2\pi n}{60} = 25\pi.$

$I_r = 35$ kg-m²

$R = 0.35$ m

$m_r = 285.71$ kg

$t = 110.45$ m

$b = 165.67$ mm

4 M

4 M.

(7) Given $P = 180\,kW$

$N = 240\,rpm$ $\sigma_t = 5.2\,MPa.$

$N_1 - N_2 = 3\%\,N.$

$\rho = 7220\,kg/m^3$

$$T_{mean} = \frac{P \times 60}{2\pi N} = 7161\,N\text{-}m$$

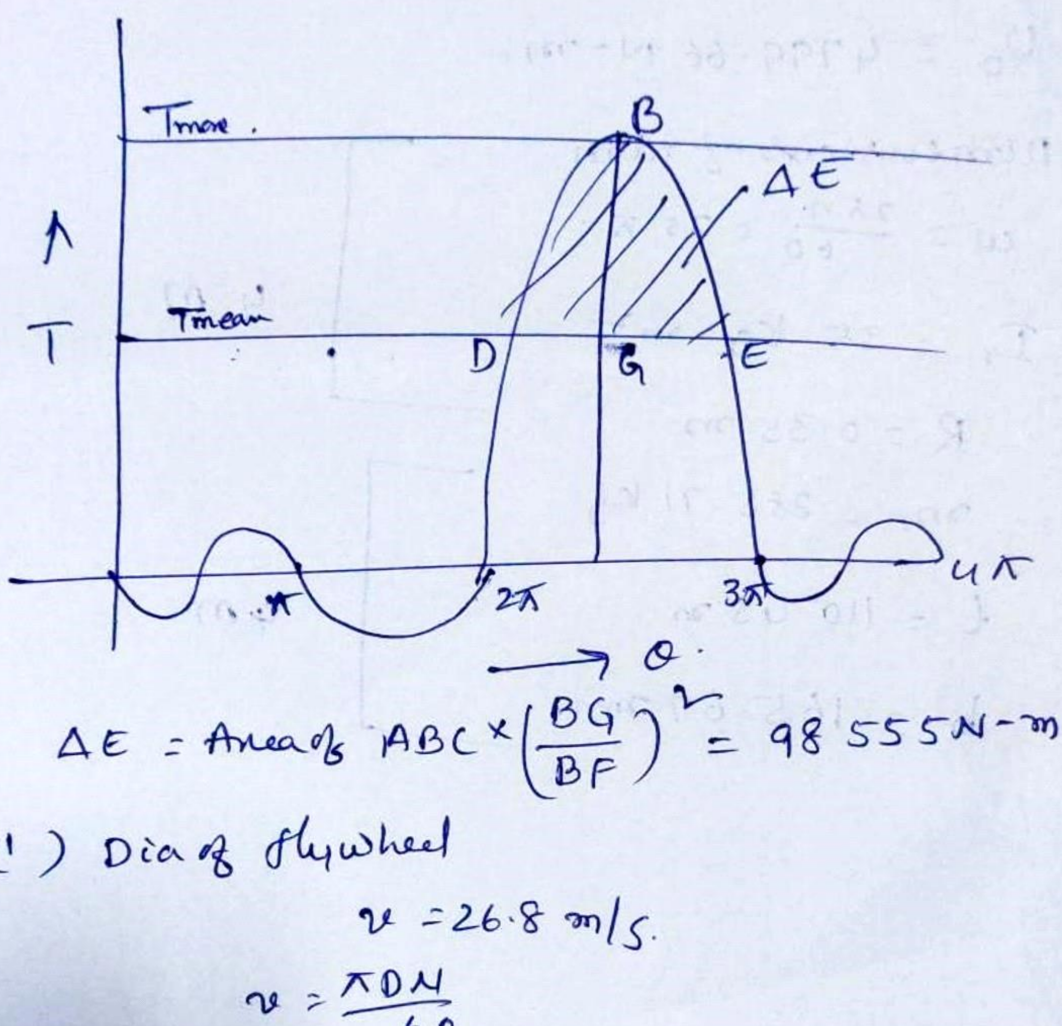
$WD/cycle = T_{mean} \times \theta$

$= 90\,000\,N\text{-}m$

$WD/stroke = 120{,}000\,N\text{-}m$

Workdone during power stroke $= \frac{1}{2}\pi\,T_{max}.$

$T_{max} = 76384\,N\text{-}m.$



$$\Delta E = \text{Area of } ABC \times \left(\frac{BG}{BF}\right)^2 = 98\,555\,N\text{-}m$$

(1) Dia of flywheel

$v = 26.8\,m/s.$

$$v = \frac{\pi D N}{60}.$$

$D = 2.04\,m.$

(2) mass of flywheel.

$$C_s = \frac{N_1 - N_2}{N}.$$

$98555 = mR^2\omega^2 C_s$

$m = 4995\,kg$

8.

Solution. Given : $D = 100$ mm ; $L = 125$ mm $= 0.125$ m ; $p = 5$ N/mm^2 ; $p_m = 0.75$ N/mm^2; $\eta_m = 80\% = 0.8$; $m = 0.15$ kg / BP / h $= 41.7 \times 10^{-6}$ kg / BP / s; $HCV = 42 \times 10^3$ kJ / kg ; $N = 2000$ r.p.m.

The dimensions for various components of the piston are determined as follows :

1. *Piston head or crown*

The thickness of the piston head or crown is determined on the basis of strength as well as on the basis of heat dissipation and the larger of the two values is adopted.

We know that the thickness of piston head on the basis of strength,

$$t_H = \sqrt{\frac{3p.D^2}{16\,\sigma_t}} = \sqrt{\frac{3 \times 5(100)^2}{16 \times 38}} = 15.7 \text{ say } 16 \text{ mm}$$

...(Taking σ_t for cast iron = 38 MPa = 38 N/mm^2)

Since the engine is a four stroke engine, therefore, the number of working strokes per minute,

$$n = N/2 = 2000/2 = 1000$$

and cross-sectional area of the cylinder,

$$A = \frac{\pi\, D^2}{4} = \frac{\pi\,(100)^2}{4} = 7855 \text{ mm}^2$$

We know that indicated power,

$$IP = \frac{p_m.L.A.n}{60} = \frac{0.75 \times 0.125 \times 7855 \times 1000}{60} = 12\ 270 \text{ W}$$
$$= 12.27 \text{ kW}$$

$\therefore$ Brake power, $BP = IP \times \eta_m = 12.27 \times 0.8 = 9.8$ kW ...($\because \eta_m = BP/IP$)

We know that the heat flowing through the piston head,

$$H = C \times HCV \times m \times BP$$
$$= 0.05 \times 42 \times 10^3 \times 41.7 \times 10^{-6} \times 9.8 = 0.86 \text{ kW} = 860 \text{ W}$$

....(Taking $C = 0.05$)

$\therefore$ Thickness of the piston head on the basis of heat dissipation,

$$t_H = \frac{H}{12.56\,k(T_C - T_E)} = \frac{860}{12.56 \times 46.6 \times 220} = 0.0067 \text{m} = 6.7 \text{mm}$$

...($\because$ For cast iron , $k = 46.6$ W/m/°C, and $T_C - T_E = 220$°C)

Taking the larger of the two values, we shall adopt

$$t_H = 16 \text{ mm} \quad \textbf{Ans.}$$

Since the ratio of L/D is 1.25, therefore a cup in the top of the piston head with a radius equal to 0.7 D (*i.e.* 70 mm) is provided.

2. *Radial ribs*

The radial ribs may be four in number. The thickness of the ribs varies from $t_H/3$ to $t_H/2$.

$\therefore$ Thickness of the ribs, $t_R = 16/3$ to $16/2 = 5.33$ to 8 mm

Let us adopt $t_R = 7$ mm **Ans.**

3. *Piston rings*

Let us assume that there are total four rings (*i.e.* $n_r = 4$) out of which three are compression rings and one is an oil ring.

We know that the radial thickness of the piston rings,

$$t_1 = D\sqrt{\frac{3\,p_w}{\sigma_t}} = 100\sqrt{\frac{3 \times 0.035}{90}} = 3.4 \text{ mm}$$

...(Taking $p_w = 0.035$ N/mm^2, and $\sigma_t = 90$ MPa)

and axial thickness of the piston rings

$$t_2 = 0.7\,t_1 \text{ to } t_1 = 0.7 \times 3.4 \text{ to } 3.4 \text{ mm} = 2.38 \text{ to } 3.4 \text{ mm}$$

Let us adopt $t_2 = 3$ mm

We also know that the minimum axial thickness of the pistion ring,

$$t_2 = \frac{D}{10\ n_r} = \frac{100}{10 \times 4} = 2.5 \text{ mm}$$

Thus the axial thickness of the piston ring as already calculated (*i.e.* $t_2 = 3$ mm)is satisfactory. **Ans.**

The distance from the top of the piston to the first ring groove, *i.e.* the width of the top land,

$$b_1 = t_H \text{ to } 1.2\ t_H = 16 \text{ to } 1.2 \times 16 \text{ mm} = 16 \text{ to } 19.2 \text{ mm}$$

and width of other ring lands,

$$b_2 = 0.75\ t_2 \text{ to } t_2 = 0.75 \times 3 \text{ to } 3 \text{ mm} = 2.25 \text{ to } 3 \text{ mm}$$

Let us adopt $b_1 = 18$ mm ; and $b_2 = 2.5$ mm **Ans.**

We know that the gap between the free ends of the ring,

$$G_1 = 3.5\ t_1 \text{ to } 4\ t_1 = 3.5 \times 3.4 \text{ to } 4 \times 3.4 \text{ mm} = 11.9 \text{ to } 13.6 \text{ mm}$$

and the gap when the ring is in the cylinder,

$$G_2 = 0.002\ D \text{ to } 0.004\ D = 0.002 \times 100 \text{ to } 0.004 \times 100 \text{ mm}$$
$$= 0.2 \text{ to } 0.4 \text{ mm}$$

Let us adopt $G_1 = 12.8$ mm ; and $G_2 = 0.3$ mm **Ans.**

4. *Piston barrel*

Since the radial depth of the piston ring grooves (b) is about 0.4 mm more than the radial thickness of the piston rings (t_1), therefore,

$$b = t_1 + 0.4 = 3.4 + 0.4 = 3.8 \text{ mm}$$

We know that the maximum thickness of barrel,

$$t_3 = 0.03\ D + b + 4.5 \text{ mm} = 0.03 \times 100 + 3.8 + 4.5 = 11.3 \text{ mm}$$

and piston wall thickness towards the open end,

$$t_4 = 0.25\ t_3 \text{ to } 0.35\ t_3 = 0.25 \times 11.3 \text{ to } 0.35 \times 11.3 = 2.8 \text{ to } 3.9 \text{ mm}$$

Let us adopt $t_4 = 3.4$ mm

p_{b1} = Bearing pressure at the small end of the connecting rod bushing in N/mm². It value for bronze bushing is taken as 25 N/mm².

We know that load on the pin due to bearing pressure

$$= \text{Bearing pressure} \times \text{Bearing area} = p_{b1} \times d_0 \times l_1$$
$$= 25 \times d_0 \times 0.45 \times 100 = 1125\ d_0 \text{ N} \quad \text{...(Taking } l_1 = 0.45\ D)$$

We also know that maximum load on the piston due to gas pressure or maximum gas load

$$= \frac{\pi\ D^2}{4} \times p = \frac{\pi\ (100)^2}{4} \times 5 = 39\ 275 \text{ N}$$

From above, we find that

$$1125\ d_0 = 39\ 275 \quad \text{or} \quad d_0 = 39\ 275 / 1125 = 34.9 \text{ say } 35 \text{ mm } \textbf{Ans.}$$

The inside diameter of the pin (d_i) is usually taken as $0.6\ d_0$.

$$\therefore \quad d_i = 0.6 \times 35 = 21 \text{ mm } \textbf{Ans.}$$

Let the piston pin be made of heat treated alloy steel for which the bending stress (σ_b)may be taken as 140 MPa. Now let us check the induced bending stress in the pin.

We know that maximum bending moment at the centre of the pin,

$$M = \frac{P.D}{8} = \frac{39\,275 \times 100}{8} = 491 \times 10^3 \text{ N-mm}$$

We also know that maximum bending moment (M),

$$491 \times 10^3 = \frac{\pi}{32}\left[\frac{(d_0)^4 - (d_i)^4}{d_0}\right]\sigma_b = \frac{\pi}{32}\left[\frac{(35)^4 - (21)^4}{35}\right]\sigma_b = 3664\,\sigma_b$$

$$\therefore \quad \sigma_b = 491 \times 10^3 / 3664 = 134 \text{ N/mm}^2 \text{ or MPa}$$

9 a.

Single variable optimization:

- A single-variable optimization problem is one in which the value of $x = x*$ is to be found in the interval [a, b] such that $x*$ minimizes $f(x)$.

$f(x)$ at $x = x*$ is said to have a

local minimum if $f(x*) \leq f(x* + h)$ for all small $\pm h$

local maximum if $f(x*) \geq f(x* + h)$ for all values of $h \approx 0$

Global minimum if $f(x*) \leq f(x)$ for all x

Global maximum if $f(x*) \geq f(x)$ for all x

MULTIVARIABLE WITH EQUALITY CONSTRAINTS

Minimize f= f(X)

Subject to the constraints

$$g_i(X) = 0, \; i = 1, 2, \ldots, m$$

where $X = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}$

- Here $m \leq n$; otherwise (if $m > n$), the problem becomes over defined and, in general, there will be no solution.
- There are several methods available for the solution of this problem

9 b.

- Golden Section is a technique to find out the extremum (maximum or minimum)of a strictly unimodal function by successively narrowing the range of values.
- This method maintains the function values for triples of points whose distances form a Golden ratio , So it's known as **Golden Section Method** or **Golden Ratio Method** or **Golden Mean Method** .
- It is developed by an American statistician **Jack Carl Kiefer** in 1956 . He also developed Fibonacci Search Method .

Main Step :

1.If $b_k - a_k < l$, stop ;

The optimal solution lies in the interval $[a_k, b_k]$.

Otherwise , if $\theta(\lambda_k) > \theta(\mu_k)$, go to Step 2 and

If $\theta(\lambda_k) \leq \theta(\mu_k)$, go to Step 3 .

2. Let $a_{k+1} = \lambda_k$ and $b_{k+1} = b_k$. Furthermore , let $\lambda_{k+1} = \mu_k$ and let $\mu_{k+1} = a_{k+1} + \alpha(b_{k+1} - a_{k+1})$. Evaluate $\theta(\mu_{k+1})$ and go to Step 4.

3. Let $a_{k+1} = a_k$ and $b_{k+1} = \mu_k$. Furthermore , let $\mu_{k+1} = \lambda_k$ and let $\lambda_{k+1} = a_{k+1} + (1-\alpha)(b_{k+1} - a_{k+1})$. Evaluate $\theta(\lambda_{k+1})$ and go to Step 4.

4. Replace k by k+1 and go to Step 1