Total No. of Questions: 6 *Total No. of Printed Pages:3*

Enrollment No......................................

Faculty of Engineering

End Sem (Even) Examination May-2022

AU3CO07 / ME3CO08 / RA3CO08 Machine Design -I

Programme: B.Tech. Branch/Specialisation: AU/ME/RA

Duration: 3 Hrs. **Maximum Marks: 60**

Note: All questions are compulsory. Internal choices, if any, are indicated. Answers of Q.1 (MCQs) should be written in full instead of only a, b, c or d. Use of design data handbook is permitted in the examination hall.

Q.1 i. Material is under fatigue failure- **1**

(a) At the elastic limit (b) Below the elastic limit

(c) At the yield point (d) Below the yield point

ii. Stress concentration is the ratio of- **1**

(a) Maximum stress to the endurance limit

(b) Nominal stress to the endurance limit

(c) Maximum stress to the nominal stress

(d) Nominal stress to the maximum stress

iii. In the transmission of power splines have major application in- **1**

(a) Pulley transmission (b) Coupling transmission

(c) Automobile transmission (d) Plastic toys

iv. Example of Rigid Coupling is- **1**

(a) Oldham Coupling (b) Clamp Coupling

(c) Bushed pin Coupling (d) Universal Coupling

v. Two shafts X and Y are made of the same material. The diameter of the shaft X is twice as that of shaft Y. The power transmitted by the shaft X will be..........................of shaft Y. **1**

(a) Twice (b) Four times (c) Eight times (d) Sixteen times

vi. Which of the loading torque is considered for the design of Axle? **1**

(a) Twisting Moment only

(b) Bending Moment only

(c) Combined Bending and Twisting Moment

(d) Combined Bending, Twisting Moment and Axial Thrust

vii. Nipping action takes place in- **1**

(a) Helical Spring (b) Torsion Spring

(c) Leaf Spring (d) Belleville Spring

P.T.O.

	viii.	When Helical Compression Spring is cut into two halves, the stiffness of the resultant spring will be- (a) Same (b) One-half (c) Double (d) One-fourth	**1**
	ix.	Factor / Factors responsible for selection of belt drive depends on- (a) Service conditions (b) Centre distance between the shafts (c) Power to be transmitted (d) All of these	**1**
	x.	Among the given below drives which is a positive drive- (a) V-belt drive (b) Chain drive (c) Rope drive (d) Crossed flat belt drive	**1**
Q.2	i.	List all the theories of failure and explain one in brief.	**2**
	ii.	Explain Notch Sensitivity with support of graph/diagram.	**3**
	iii.	A torsion bar, 1 meter long is to be designed. The shear modulus of the bar is 84 kN/mm^2. Determine the required diameter of the solid bar, so that the resulting torsional spring constant (torsional stiffness) of the bar is 28 Nm per degree of angular twist of the bar.	**5**
OR	iv.	What is the difference between Gerber curve and Soderberg and Goodman lines?	**5**
Q.3	i.	Explain types of keys with free hand sketch.	**2**
	ii.	Draw as your convenient scale front view of Unprotective Type Flange Coupling with empirical dimensions.	**3**
	iii.	Design a rectangular key for the shaft of 55 mm diameter. The shearing and crushing stresses for the key material are 45 MPa and 75 MPa respectively.	**5**
OR	iv.	Design a Clamp Coupling for transmitting 36 kW, at 200 r.p.m. Allowable shear stress in shaft is 45 MPa, allowable shear stress in key is 40 MPa and allowable crushing stress in key is 90 MPa. The number of bolts joining the two halves is 4. The permissible tensile stress in bolts is 60 MPa. The coefficient of friction between the muff and the shaft can be taken as 0.25.	**5**
Q.4	i.	List some of the materials and properties of shaft materials.	**2**
	ii.	Find the diameter of a solid shaft to transmit 22 kW at 210 r.p.m. The ultimate shear stress for the material may be 365 MPa and a factor of safety as 7.5. If a hollow shaft is to be used in place of solid shaft of same material, find the inside and outside diameter when the ratio of inside to outside diameter is 0.5.	**8**

OR	iii.	A steel shaft transmits 22 kW at 210 r.p.m. It carries a central load of 910 N and is simply supported between the bearings 2.4 metres apart. Determine the size of the shaft, if allowable shear stress is 43 MPa and the maximum tensile or compressive stress is not to exceed 57 MPa. What size of the shaft will be required, if it is subjected to gradually applied loads?	**8**
Q.5	i.	Explain the nipping process in relation to springs.	**2**
	ii.	A helical compression spring is made of hard-drawn wire of 18 SWG (1.219mm inner diameter). The outer diameter of the spring is 12.5mm. Estimate (a) Torsional yield strength of the material. (b) Static load corresponding to yield strength (c) Deflection due to this static load if the number of total turns is 13.5 (d) Solid length of the spring.	**8**
OR	iii.	Determine the cross-section of the leaves of a carriage spring of semi-elliptical shape, used as a suspension of a bus. There are 2 full length leaves (including master leaf) and 8 graduated leaves. Spring eyes are located at 1180 mm. Take factor of safety as 2. Maximum load on spring may be taken as 40kN safe stress of the material of the spring is 1400 MPa.	**8**
Q.6		Attempt any two:	
	i.	Give five differences between rope drives, chain drives and belt drives.	**5**
	ii.	Procedure for designing a chain drive.	**5**
	iii.	A belt 98 mm wide and 9 mm thick is transmitting power at 998 metres/min. The net driving tension is 1.8 times the tension on the slack side. If the safe permissible stress on the belt tension is 1.6 MPa, calculate the maximum power that can be transmitted at this speed. Assume density of the leather as 1000 Kg/m^3. Calculate the absolute maximum power that can be transmitted by this belt and the speed at which this can be transmitted.	**5**

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END SEM EXAMINATION MAY-2022

PAPER SOLUTION & SCHEME OF MARKING

Programme : B.Tech Course Name : Machine Design
Branch : AU/ME/RA Course Code : AU3C007/ME3C008/RA3C008

MCQ

Q1 (i)	(d)	Below the yield point	1
(ii)	(c)	Maximum stress to the Nominal stress	1
(iii)	(c)	Automobile Transmission	1
(iv)	(b)	Clamp Coupling	1
(v)	(c)	Eight Times	1
(vi)	(b)	Bending Moment Only	1
(vii)	(c)	Leaf Spring	1
(viii)	(c)	Double	1
(ix)	(d)	All of these	1
(x)	(b)	Chain drive	1

Q2 (iii) Given

$l = 1\,m = 1000\,mm$

$G = 84\,kN/mm^2$

$T/\theta = 28\,N\text{-}m/degree$

Torsion Equation

$$\frac{T}{J} = \frac{G\theta}{l}$$

$$\frac{T}{\theta} = \frac{G \cdot J}{l} = \frac{G \cdot \frac{\pi}{32} d^4}{l}$$

$$\frac{T}{\theta} = \frac{G \cdot \pi \cdot d^4}{32 \cdot l} = \frac{84 \times 10^3 \times \pi \times d^4}{32 \times 1000}$$

5

$$\frac{T}{\theta} = 8.24 d^4 \quad \therefore \frac{T}{\theta} = 28 \times 10^3 = 8.24\,d^4$$

$d^4 = 3395.3$ or $\boxed{d \Rightarrow 7.633\,mm}$

Q3 (iii) Given

Shaft diameter $d = 55\,mm$

shear stress $\tau = 45\,MPa$

Crushing stress $\sigma_c = 75\,MPa$

From Data Book, for shaft diameter 55 mm.

$$\boxed{\begin{array}{l} w = 16\,mm \\ t = 10\,mm \end{array}}$$

Length of key $= l$. 1

Considering shear

$$T = l \times w \times \tau \times \frac{d}{2} = l \times 16 \times 45 \times \frac{55}{2} = 19800\,l \quad \text{-- eq(i)}$$

$$\text{Torque Transmitted} = \frac{\pi}{16} \cdot d^3 \cdot \tau = \frac{\pi}{16} (55)^3 \cdot 45 = 1.47 \times 10^6\,N\text{-}mm$$

1

$$\text{Torque } T = 1.47 \times 10^6\,N\text{-}mm \quad \text{-- eq(ii)}$$

From eq(i) & eq(ii)

$$19800\,l = 1.47 \times 10^6$$

$$l = 74.24 \text{ mm}$$ 1

Now considering crushing

$$T = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2} = l \times \frac{10}{2} \times 75 \times \frac{55}{2}$$

$$T = 10312.5\,l \quad \ldots \text{eq(iii)}$$

From eq (ii) & eq(iii) 1

$$10312.5\,l = 1.47 \times 10^6$$

$$l = 142 \text{ mm}$$

Taking larger of the two values.

$$\boxed{l = 142 \text{ mm}}$$ 1

(iv)

CLAMP COUPLING

Given : $P = 36\text{ KW}$

$N = 200 \text{ rpm}$

$\tau_{shaft} = 45 \text{ MPa}$

$\tau_{key} = 40 \text{ MPa}$

$\sigma_c = 90 \text{ MPa}$

$n = 4$

$\sigma_t = 60 \text{ MPa}$

$\mu = 0.25$

1. Design for shaft

Let d = diameter of shaft

Torque $T = \frac{P \times 60}{2\pi N} = \frac{36 \times 10^3 \times 60}{2\pi \times 200} = 1718.9$ N-m 1

Torque Transmitted by shaft.

$$T = \frac{\pi}{16} d^3 \cdot \tau = \frac{\pi}{16} \cdot d^3 \cdot 45$$

$$1718.9 \times 10^3 = \frac{\pi}{16} \cdot d^3 \cdot 45$$

$$d^3 = \frac{16 \times 1718.9 \times 10^3}{45\pi} = 194536.67$$ 1

$$\boxed{d = 57.94 \text{ mm} = 60 \text{ mm}}$$

2. Design for muff

$$D = 2d + 13 = 2 \times 60 + 13 = 133 \text{ mm}$$ 1

$$D = 133 \text{ mm}$$

Total Length of muff.

$$L = 3.5d = 3.5 \times 60 = 210 \text{ mm}$$

$$L = 210 \text{ mm}$$

1

3. Design for key.

The width & thickness of the key for a shaft diameter of 60 mm. [Design Data book]

$b = 18$ mm

$t = 11$ mm

4. Design for bolts 1

Let d_b = Root or core diameter

Torque Transmitted (T),

$$T = \frac{\pi^2}{16} \cdot \mu \cdot (d_b)^2 \cdot \sigma_t \times n \times d = \frac{\pi^2}{16} \cdot 0.25 \cdot (d_b)^2 \cdot 60 \times 4 \times 60$$

$$1718.9 \times 10^3 = 2220.67 \cdot d_b^2$$

$$\boxed{d_b = 27.82 = 28\ mm}$$

Q4. (ii) Given
$P = 22\ KW$
$N = 210\ rpm$
$\tau_u = 365\ MPa$
$FS = 7.5$

1

Allowable shear stress $\tau = \frac{\tau_u}{FS} = \frac{365}{7.5} = 48.67\ MPa$

Torque Transmitted by shaft

$$T = \frac{P \times 60}{2\pi N} = \frac{22 \times 10^3 \times 60}{420\pi} = 1000.4\ N\text{-}m$$

$$\boxed{T = 1000.4 \times 10^3\ N\text{-}mm}$$ 1

1. Diameter of solid shaft.

$$T = \frac{\pi}{16} \cdot d^3 \cdot \tau = \frac{\pi}{16} \cdot d^3 \cdot 48.67 = 1000.4 \times 10^3$$

$$d^3 = \frac{1000.4 \times 10^3 \times 16}{48.67\pi} = 104684.77$$

2

$$\boxed{d = 47.12 = 50\ mm}$$

2. Diameter of Hollow shaft. $K = 0.5$

Let d_i = Inside diameter

d_o = Outside diameter

Torque $T = \frac{\pi}{16} \cdot \tau \cdot d_o^3 (1 - K^4)$

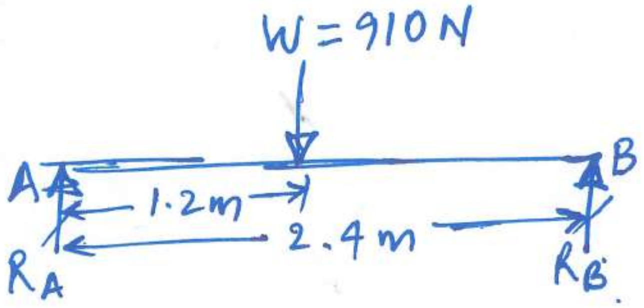
$1000.4 \times 10^3 = \frac{\pi}{16} \cdot 48.67 \times d_o^3 \times (1 - 0.5^4)$ 4

$d_o^3 = \frac{1000.4 \times 10^3 \times 16}{48.67 \pi \times 0.9375} = 111663.48$

$d_o = 48.15$ mm or 50 mm

$\boxed{d_o = 50 mm, \ d_i = 25 mm}$

Q4(iii) Given



$P = 22$ KW

$N = 210$ rpm

$W = 910$ N

$l = 2.4$ m

$\tau = 43$ MPa

$\sigma \Rightarrow 57$ MPa

Torque Transmitted by shaft.

$T = \frac{P \times 60}{2\pi N} = \frac{22 \times 10^3 \times 60}{210 \pi \times 2} = 1000.4$ 1

$T = 1000.4$ N-m $= 1000.4 \times 10^3$ N-mm

Bending Moment transmitted by shaft.

$$M = \frac{W.l}{4} \Rightarrow \frac{910 \times 2.4 \times 10^3}{4} \Rightarrow 5.46 \times 10^5 \text{ N·mm}$$

$$\underline{M = 5.46 \times 10^5 \text{ N-mm}}$$ (1)

(i)

A) Maximum shear stress Theory.

$$T_e \Rightarrow \sqrt{M^2 + T^2} = \frac{\pi}{16} \cdot d^3 \cdot \tau$$

$$T_e = \sqrt{(5.46 \times 10^5)^2 + (1000.4 \times 10^3)^2} = 1.139 \times 10^6 \text{ N-mm}$$

$$1.139 \times 10^6 = \frac{\pi}{16} \cdot d^3 \cdot 43.$$ (1.5)

$$\boxed{d = 51.29 = 55 \text{ mm}}$$ (3)

B) Maximum Normal stress Theory.

$$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right] = \frac{\pi}{32} \cdot \sigma_b \cdot d^3$$

$$= \frac{1}{2}\left[(5.46 \times 10^5) + \sqrt{(5.46 \times 10^5)^2 + (1000.4 \times 10^3)^2}\right]$$

$$\Rightarrow \frac{1}{2}\left[5.46 \times 10^5 + 1.139 \times 10^6\right] \Rightarrow 8.42 \times 10^3 \text{ N-mm}$$

$$Me = 8.425 \times 10^3 = \frac{\pi}{32} \cdot 57 \times d^3$$ (1.5)

(3)

$$d^3 \Rightarrow 150555$$

$$\boxed{d = 53.2 \simeq 55 \text{ mm}}$$

Both dia same. $\underline{d = 55 \text{ mm}}$ Ans

(ii) If the load is applied Gradually.

$K_m = 1.5$ from Data Book.
$K_t = 1.$

$$T_e = \sqrt{(K_m \cdot M)^2 + (K_t \cdot T)^2}$$

$$\Rightarrow \sqrt{(1.5 \times 5.46 \times 10^5)^2 + (1000.4 \times 10^3 \times 1)^2}$$

$$T_e \Rightarrow 1.293 \times 10^6 \text{ N-mm}$$ (.5)

$$T_e = \frac{\pi}{16} \cdot d^3 \cdot \tau \Rightarrow \frac{\pi}{16} \cdot d^3 \cdot 43$$

$$\boxed{d = 53.5 \text{ mm}}$$

$$M_e \Rightarrow \frac{1}{2}\left[K_m M + \sqrt{(K_m \cdot M)^2 + (K_t \cdot T)^2}\right]$$

$$\Rightarrow \frac{1}{2}\left[K_m \cdot M + T_e\right]$$

$$\Rightarrow \frac{1}{2}\left[1.5 \times 5.46 \times 10^5 + 1.293 \times 10^6\right]$$

$$M_e = 1.056 \times 10^6.$$ (1.5)

$$M_e = \frac{\pi}{32} \cdot d^3 \cdot \sigma_t = \frac{\pi}{32} \cdot d^3 \cdot 57$$

$$\boxed{d = 57.35 \simeq 60 \text{ mm}}$$

Taking larger of two values.

$d = 60$ mm Ans.

Q5 (ii) For 18 SWG = 1.219 mm

$G = 80.7\, GPa$, for hard drawn wire

$m = 0.190$

$A = 1783$

Ultimate strength $\sigma_u = \frac{A}{d^m} = \frac{1783}{1.219^{0.190}}$

$\sigma_u = 1717\ MPa$

(a) Torsional yield strength of the Material

$\tau_y = 0.35 - 0.5\,\sigma_u = 0.4 \cdot \sigma_u$ (approx)

$\boxed{\tau_y \Rightarrow 0.4 \times 1717 \Rightarrow 687\ MPa}$ 2

(b) Static load corresponding to yeild strength

$\tau_{ys} = K_s \frac{8WD}{\pi d^3}$ Outer Dia $D_0 = 12.5\ mm$

Mean coil dia $= D_0 - d = 12.5 - 1.219\ mm$

$\boxed{D = 11.281\ mm}$

$K_s = 1 + \frac{1}{2C}$

$\boxed{C = \frac{D}{d} = \frac{11.281}{1.219} = 9.254}$

$K_s = 1 + \frac{1}{2 \times 9.254} = 1.054$

$\boxed{K_s = 1.054}$

$$\tau_{ys} = \frac{8WD}{\pi d^2} \cdot K_s = \frac{8 \cdot W \cdot 11.281}{\pi \cdot (1.219)^2} \times 1.054$$

$687 \Rightarrow W \cdot 16.71$

$$\boxed{W = 41.1\ N}$$

2

(c) Deflection due to static load if the total No. of turns is 13.5

$N_t = 13.5$ For square ends

$n = N_t - 2 \Rightarrow 11.5$

n = No of Active Turns

2

$$\delta = \frac{8W \cdot D^3 \cdot n}{G \cdot d^4} = \frac{8 \times 41.1 \times (11.281)^3 \times 11.5}{80.7 \times 1000 \times (1.219)^4}$$

$$\boxed{\delta = 30.463\ mm}$$

(d) Solid Length

$L_s = (N_t - 1)d = (13.5 - 1)1.219$

$$\boxed{L_s = 15.2375\ mm}$$

2

Q 5(iii)

$n_F = 2$

$n_G = 8$

$2L_1 = 1180\ mm\ ;\ L_1 = 590\ mm$

$FS = 2.$

$2W = 40KN\ ;\ W = 20KN.$

$\sigma = 1400\ MPa$

$n = n_F + n_G = 2 + 8 = 10$

Designing stress $= \dfrac{\sigma}{FS}$

(2)

$\sigma_d = \dfrac{1400}{2} = 700 MPa$

(2)

$$\sigma_d = \frac{6 \cdot W L_1}{n \cdot b t^2} = \frac{6 \times 20 \times 10^3 \times 590}{10 \times b \times t^2}$$

$$b t^2 = \frac{6 \times 20 \times 10^3 \times 590}{10 \times 700}$$

$$b t^2 \Rightarrow 1011.4$$

(4)

Assuming a standard width of 60.

$b = 60,$ $\quad t^2 = \dfrac{1011.4}{60} \Rightarrow 168.5$

$t = 12.98 = 13\ mm.$

$$\boxed{\begin{array}{l} b = 60\ mm \\ t = 13\ mm \end{array}}$$

Q6 (iii) Given

$b = 98\ mm$

$t = 9\ mm$

$v = 998\ m/min \Rightarrow 16.63\ m/sec$

$(T_1 - T_2) = 1.8\ T_2$

$\sigma = 1.6\ MPa$

$P_{max} = 2$

$\rho = 1000\ kg/m^3$

Power Transmitted.

Let T_1 = Tension in Tight side

T_2 = Tension in slack side.

$T \Rightarrow \sigma . b . t = 1.6 \times 98 \times 9 = 1411.2\ N$

$m = $ Area x Length x density

$= b \times t \times l \times \rho = \cancel{98 \times 9}$

$\Rightarrow 0.098 \times 0.009 \times 1 \times 1000 \Rightarrow 0.882\ \frac{kg}{m}$

$$\boxed{m = 0.882\ kg/m.}$$

Centrifugal Tension (T_c)

$T_c = m . v^2 \Rightarrow 0.882 \times \left(\frac{998}{60}\right)^2$

$$\boxed{T_c = 244\ N.}$$

$T_1 = T - T_c = 1411 - 244 = 1167\,N.$

$$\boxed{T_1 = 1167\,N.}$$

$T_1 - T_2 = 1.8\,T_2$

$T_1 = 2.8\,T_2$ $\qquad \boxed{T_2 = \frac{T_1}{2.8} = 416.78\,N.}$

$P = (T_1 - T_2) \cdot v = (1167 - 416.78) \cdot 16.63 = 12476\,W$

$$\boxed{P = 12.476\,kW} \quad (3)$$

Speed at which maximum power can be transmitted

$$v = \sqrt{\frac{T}{3m}} = \sqrt{\frac{1411.2}{3 \times 0.882}} \Rightarrow 23.09\,m/s$$

$$\boxed{v = 23.09\,m/s.}$$

Absolute Maximum Power

$T_c = \frac{T}{3} = \frac{1411.2}{3} \Rightarrow 470.4\,N.$

$T_1 = T - T_c = 1411.2 - 470.4 = 940.8\,N$

$\underline{T_1 = 940.8\,N}$

$T_2 = \frac{T_1}{2.8} = 336 \qquad \underline{T_2 = 336\,N}$

$P = (T_1 - T_2) \cdot v = (940.8 - 336) \cdot 16.63 = 10{,}057.$

$$\boxed{P = 10.057\,kW}. \quad (2)$$