BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND ENGINEERING

AEH311(2)

Department of Engineering and Physics
Bachelor of Science (Honours) Degree in Agricultural Engineering Part III

Agricultural Engineering Design

3 HOURS (100 Marks)

INSTRUCTIONS

Answer any **FOUR** questions. Each carries **25 marks**

---

1. a) Briefly explain the following procedure stages used to solve a design problem:

(i) Recognition of need, **[2 marks]**
(ii) Synthesis, **[2 marks]**
(iii) Analysis of forces, **[2 marks]**
(iv) Material selection, **[2 marks]**
(v) Design of elements, **[2 marks]**
(vi) Modification, **[2 marks]**
(vii) Detailed drawing, and **[2 marks]**
(viii) Production. **[2 marks]**

b) Estimate the power output capacity of a 20^0 pressure angle involute gear set manufactured from 653M31 (En 23) steel alloy shown in Table Q1. The 18 teeth pinion meshes with a 34 tooth gear. The gear are cut with a module of 2.5 mm and the face width is 34 mm. the pinion rotates at 1440 rpm. A factor of safety of 9 may be assumed. **[9 marks]**

$$\left[\sigma_b = \frac{F_t}{mbYK_v};\quad \sigma = \frac{nF_t}{mbYK_v}\right]$$

Table Q1: Gear Manufacturing Materials

Material	Characteristic	$\sigma_{ut}(MPa)$
PB102 (BS2870)	5% Phosphor Bronze, Friction Resistant	430
826M31(En 25)	Shock Resistant	1010
832M13 (En 36C)	Shock Resistant	1000
653M31 (En 23)	Withstand low Temperature Impact	760
530A40 (En18D)	Shock and Wear Resistant	620
214M15 (En 20)	Light duty pinions	550

2. a) A solid steel shaft is subjected to a bending moment of 12.1 kNm and a twisting moment of 5.6 kNm. If the allowable shear stress is 800 MPa determine the diameter of shaft needed. **[5 marks]**

b) A solid shaft required to drive a crusher is to be mounted between two self-aligning bearings 0.8 m apart, and will be driven off a 115 kW power source, rotating at 270 rpm to a 288 mm pitch circle diameter gear situated between the bearings and 0.3 m from the left hand bearing. The gear pressure angle is 20^0. The shaft is to be manufactured from BS970: 070M20 steel (normalised) and a crusher shaft may be considered as subjected to major shock.

i) Determine the maximum torque. **[5 marks]**

ii) Ignoring the weight of the shaft and gear, determine a suitable shaft diameter by using a factor of safety of 2. Make use of the maximum shear stress theory of failure. **[10 marks]**

iii) Draw the bending moment diagram. **[5 marks]**

[BHN = 125, LRS = 63, $\sigma_{yt} = 215MPa$].

$$\left[\tau_{max} = \frac{16}{\pi d^3}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}\right];\ \tau_{max} = \frac{16}{\pi d^3}\sqrt{M_t^2 + (\frac{Pd}{8})^2};\ \frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{L};\ Z = \frac{\pi d^3}{16};$$

$$\tau = \frac{16M}{\pi d^3};\ I = \frac{\pi d^4}{64};\ \tau_{max} = \sqrt{\sigma_b^2 + 4r^2};\ \tau_{max} = \frac{16}{\pi d^3}\sqrt{M_t^2 + M_b^2}$$

3. a) A pulley bracket as shown below is supported by 4 bolts, 2 at AA and 2 at BB. The weight of pulley and bracket W is 1 kN and the load P on the rope is 30 kN. If the allowable tensile stress of the bolt material is 45 MN/m^2, determine the diameter of bolts to be used. **[13 marks]**

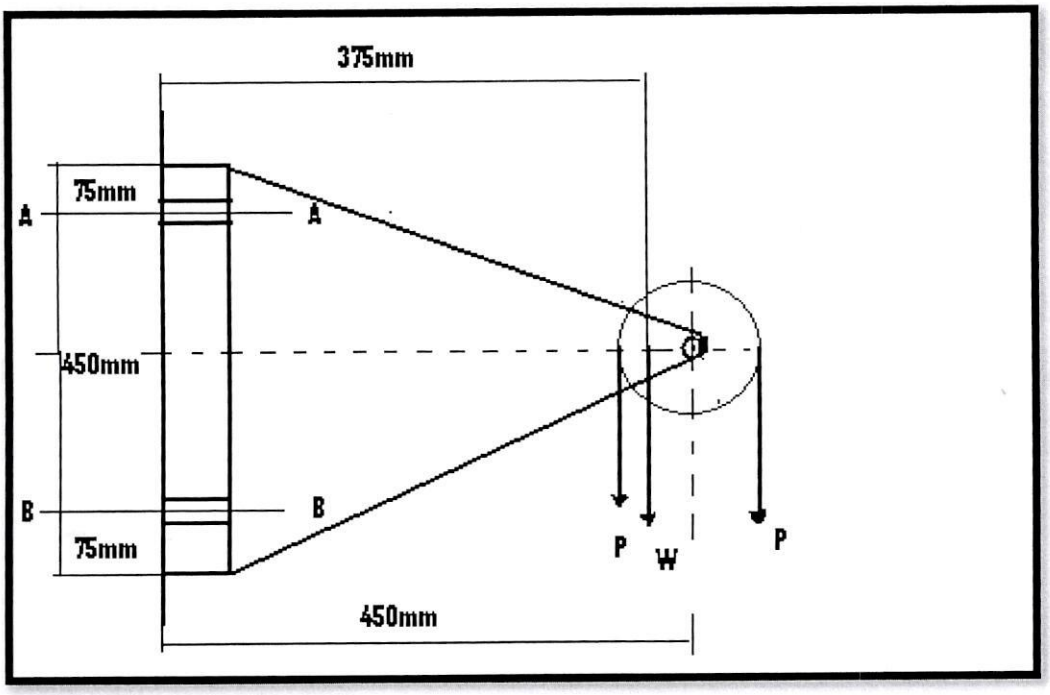


Figure Q3: Pulley Bracket

b) A bar of cross section $50 \times 30\ mm$ is shown below. Determine:

i) The size of the weld when an axial load 80 kN is applied considering that the allowable stress in the weld is 100 MNm^2. **[6 marks]**

ii) The induced stress in the 5 mm thick weld when a transverse load of 2 KN is applied at a distance of 250 mm from the weld area. **[6 marks]**

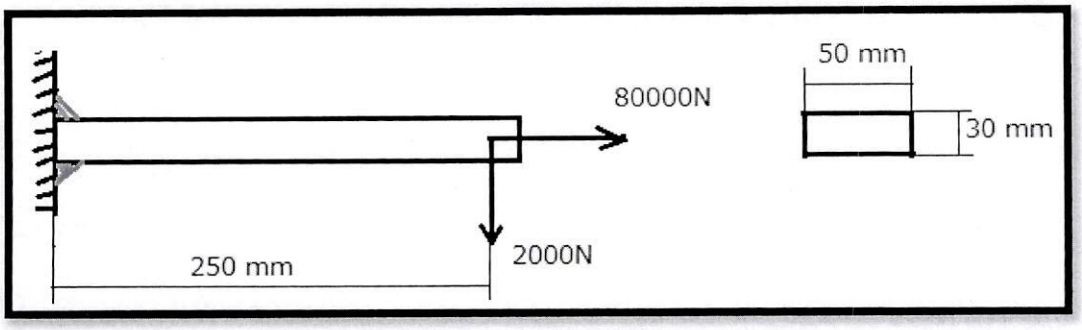


Figure Q3 (b): Welded Bar

$$\sigma_t = \frac{4P}{\pi d_c^2}: \quad T = \frac{Pd_p}{2}\tan(\alpha + \emptyset): \ \tau = \frac{Td_p}{2J} = \frac{32Ptan(\alpha + \emptyset)}{\pi d_p^2}$$

$$\sigma_{12} = \frac{1}{2}\left[\sigma \pm \sqrt{\sigma^2 + 4\tau^2}\right]: \ F_1 - F_2 = \frac{PK_g}{K_g + K_b}: \ F_1 = F\left(\gamma + \frac{K_g}{K_g + K_b}\right)$$

$$F_R = F_1 + KF: \ \sigma_{te} = \sigma_t \pm \frac{1}{2}\sqrt{\sigma_t^2 + 4\tau^2}: \ \sigma = \frac{F}{hl}: \ \sigma_1 = 1.618\frac{F}{hl}: \ \tau = \frac{1.414F}{hl}$$

$$\tau^{11} = \frac{rM}{J}: \ I^{11} = \frac{1.414M}{bdh}: \ \tau_{max} = \sqrt{\tau_1^2 + \tau_2^2 + 2\tau_1\tau_2 cos\theta}: \ \tau_1 = \frac{F}{tlCos45}$$

$$\tau_2 = \frac{Fe\sqrt{a^2 + b^2}}{2J}$$

4. a) A chain is to actuate a compressor from an electric motor rated at 13.2 kW at 1000 rpm, the compressor speed being 400 rpm. If the minimum center distance should be 650 mm. The pitch 20 mm, the roller diameter 12.07mm, the minimum width of roller 11.68 mm, the maximum (breaking) load 6000 kg and the sprocket pinion has 25 teeth, calculate:
   a) The pitch diameters of the pinion and wheel sprockets. **[5 marks]**
   b) The factor of safety. **[10 marks]**
   c) The bearing pressure on the roller. **[5 marks]**
   d) The length of the chain. **[3 marks]**
   e) The actual center distance. **[2 marks]**

$$Q = \frac{T_1 c^5 - 1}{c - 1} \qquad Q = \frac{P(c^5 - 1)}{c^5(c - 1)} \qquad P = \frac{Qc^5(c - 1)}{c^5 - 1}$$

$$\eta = \frac{c^5 - 1}{5c^5(c - 1)} \qquad P = \frac{c - 1}{c(c^5 - 1)}Q \qquad p = \frac{2F}{Dd}$$

$$F_b = E_r A\frac{d_w}{D} \qquad n = \frac{F_a - F_b}{F_w} \qquad F_w + F_b \le \frac{F_{max}}{f.o.s.}$$

$$V = V_c Cos\left(\frac{\alpha}{2}\right) = \omega r Cos\left(\frac{\alpha}{2}\right) \qquad Sin(\frac{\alpha}{2}) = \frac{p}{D} \qquad D = \frac{P}{Sin(\frac{180}{T})}$$

$$L = \frac{T_1 + T_2}{2} + \frac{2C}{p} + \frac{p}{C}\left[\frac{T_1 - T_2}{2\pi}\right]^2 \qquad C^1 = \frac{e + \sqrt{(e^2 + 8m)}}{4} pitches$$

$$\sigma_c = \frac{F}{wd_r}$$

5. a) Briefly describe the following terms with reference to springs:

i) Severe service, **[2 marks]**

ii) Average service, and **[2 marks]**

iii) Light service. **[2 marks]**

b) A compressive helical spring is to carry a load of 1.5 kN The spring deflection is 40 mm. Considering the space limitations, the spring index may be taken as 5. The shear stress in spring wire should not exceed 400 MN/m^2, the modulus of rigidity for the spring material is 80 GN/m^2. Determine:

i. The wire and the coil diameters. **[10 marks]**

ii. The number of active turns of coil. **[4 marks]**

iii. The free length of the spring taking 1mm clearance between adjacent coils. $[l = nd + d + c]$ **[5 marks]**

$$\left[\delta = \frac{8FD^3n}{Gd^4}\right] and \left[\tau_s = \frac{8FDK}{\pi d^3}\right]$$

6 a) Briefly explain the following types of brakes stating one example for each:

i) Hydraulic brakes, **[2 marks]**

ii) Electric brakes, and **[2 marks]**

iii) Mechanical brakes. **[2 marks]**

b) A 700 mm diameter brake drum contacts a single shoe as shown below. The brake is to operate against a 225 Nm torque at 500 rpm. μ = 0.3. Determine:

i. The normal force F on the shoe. **[3 marks]**

ii. The required force W to apply the brake for clockwise rotation. **[4 marks]**

iii. The required force W to apply the brake for anti-clockwise rotation. **[4 marks]**

iv. The dimension that c would need to be to make the brake self-locking. **[4 marks]**

v. The rate of heat generated. **[4 marks]**

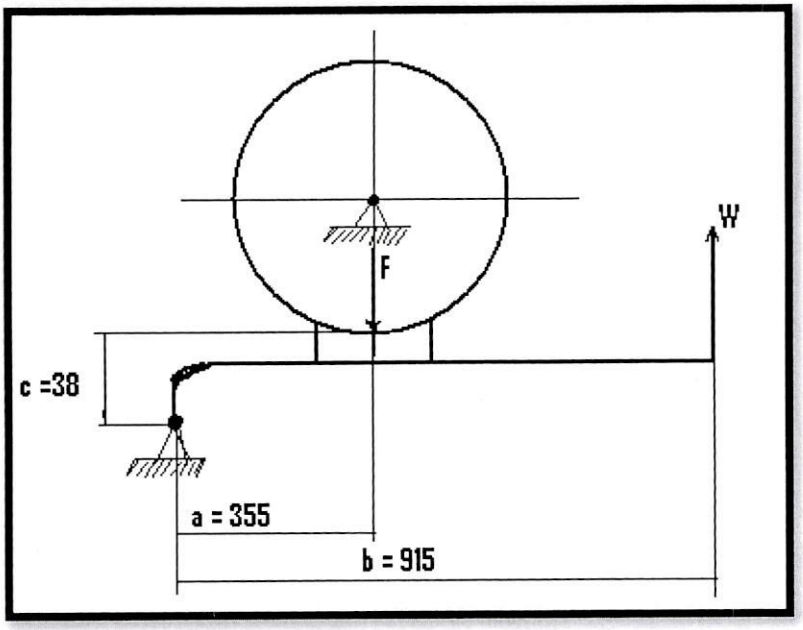
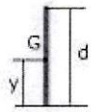
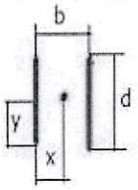
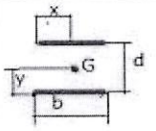
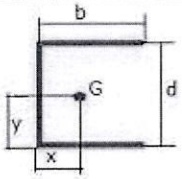
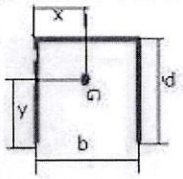
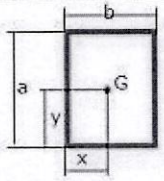
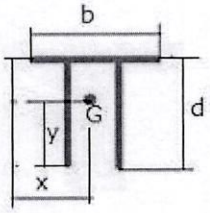


Figure Q6(b): Brake Drum

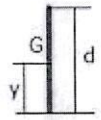
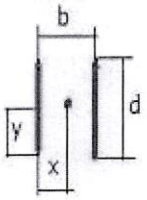
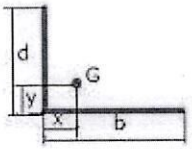
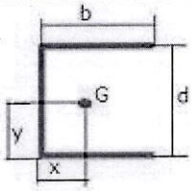
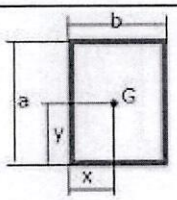
$$T = 2kbr^2\mu sin\theta; \qquad \mu' = \frac{\mu 4Sin\theta}{2\theta + sin2\theta}; \qquad T = \frac{4r\mu F sin\theta}{2\theta + sin2\theta}; \qquad T = (F_{tR} + F_{tL})r$$

Appendix

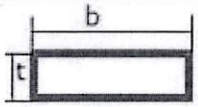
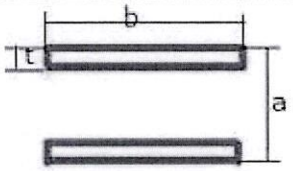
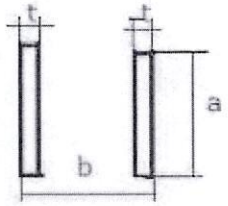
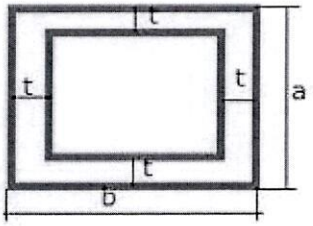
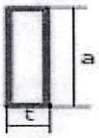
LIST OF BENDING PROPERTIES OF FILLET WELDS

Weld	Throat area	Location of G	I_u
	A = 0,707hl	x = 0 $y = \frac{d}{2}$	$I_u = \frac{d^2}{12}$
	A = 1.414dh	$x = \frac{b}{2}$ $y = \frac{d}{2}$	$I_u = \frac{d^3}{6}$
	A = 1.414bh	$x = \frac{b}{2}$ $y = \frac{d}{2}$	$I_u = \frac{bd^2}{2}$
	A = 0.707h(2b+d)	$x = \frac{b^2}{2b+d}$ $y = \frac{d}{2}$	$I_u = \frac{d^2}{12}(6b+d)$
	A = 0.707h(b + 2d)	$x = \frac{b}{2}$ $y = \frac{d^2}{b+2d}$	$I_u = \frac{2d^3}{3} - 2dy + (b+2d)y^2$
	A = 1.414h(b + d)	$x = \frac{b}{2}$ $y = \frac{d}{2}$	$I_u = \frac{d^2}{6}(3b+d)$
	A = 0.707h(b +2d)	$x = \frac{b}{2}$ $y = \frac{d^2}{b+2d}$	$I_u = \frac{2d^3}{3} - 2d^2y + (b+2d)y$

LIST OF THROAT AREAS AND UNIT SECOND POLAR MOMENTS OF AREA FOR COMMON FILLET WELDS USED.

Weld	Throat area	Location of G	Unit second polar moment of area
	A = 0.707hd	x= 0 $y=\frac{d}{2}$	$J_u=\frac{d^3}{12}$
	A = 1.414hd	$x=\frac{b}{2}$ $y=\frac{d}{2}$	$J_u=\frac{(3b^3+d^3)d}{6}$
	A = 0.707h(2b+d)	$x=\frac{b^2}{2}(b+d)$ $y=\frac{d^2}{2}(b+d)$	$J_u=\frac{(b+d)^4-6b^2d^2}{12(b+d)}$
	A = 0.707h(2b+d)	$x=\frac{b^2}{(2b+d)}$ $y=\frac{d}{2}$	$J_u=\frac{8b^3+6bd^2+d^3}{12}-\frac{b^4}{2b+d}$
	A = 1.414h(b+d)	$x=\frac{b}{2}$ $y=\frac{d}{2}$	$J_u=\frac{(b+d)^3}{6}$

VALUES OF J (Polar Moment of Inertia)

	$J = \frac{tb^3}{12}$
	$J = \frac{bt(3a^2 + b^2)}{6}$
	$J = \frac{at(a^2 + 3b^2)}{6}$
	$J = \frac{t(a+b)^3}{6}$
	$J = \frac{ta^3}{12}$