The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

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Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	: **DMX4306 Design of Machine Elements**
Academic Year	: 2022/23
Date	: February 15, 2024
Time	: 13.30 hrs. -17.30 hrs.
Duration	: **4 hours**

General Instructions: *READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE ANSWERING THE QUESTION PAPER.*

1. This question paper has two parts, **PART A** and **PART B**. Part A consists of Question 1 and Part B consists of Questions 2,3 and 4. **Answer all the questions**.

2. Answers to the question in PART A carries **50** marks, whereas in PART B, each **17** marks.

3. **Attempt all parts in Question 1** in that given order. Spend approximately 2 hours and 45 minutes to answer the Question 1 in PART A and rest for Questions in PART B.

4. Wherever appropriate, use the given catalogue, information, and data sheets, provided to you in the examination hall. At the end of the examination return all such material to the examiner/ supervisor of the examination hall. You will be provided with, *1*. Instruction booklet of spur and helical gear design, *2*. Motor catalog, *3*. Bearing selection manual, *4*. Handbook of metric keys and keyways and *5*. Handbook of V-belt drives as per your request.

5. **Any missing data can be sensibly and reasonably assumed**, but such assumptions are not acceptable unless they are justified and clearly stated.

6. Wherever relevant use neatly drawn sketches to explain your answers.

7. Any result from calculations should have units unless they are dimensionless.

8. All answers to the given questions should be underlined for the purpose of easy identification.

PART A

Question 1

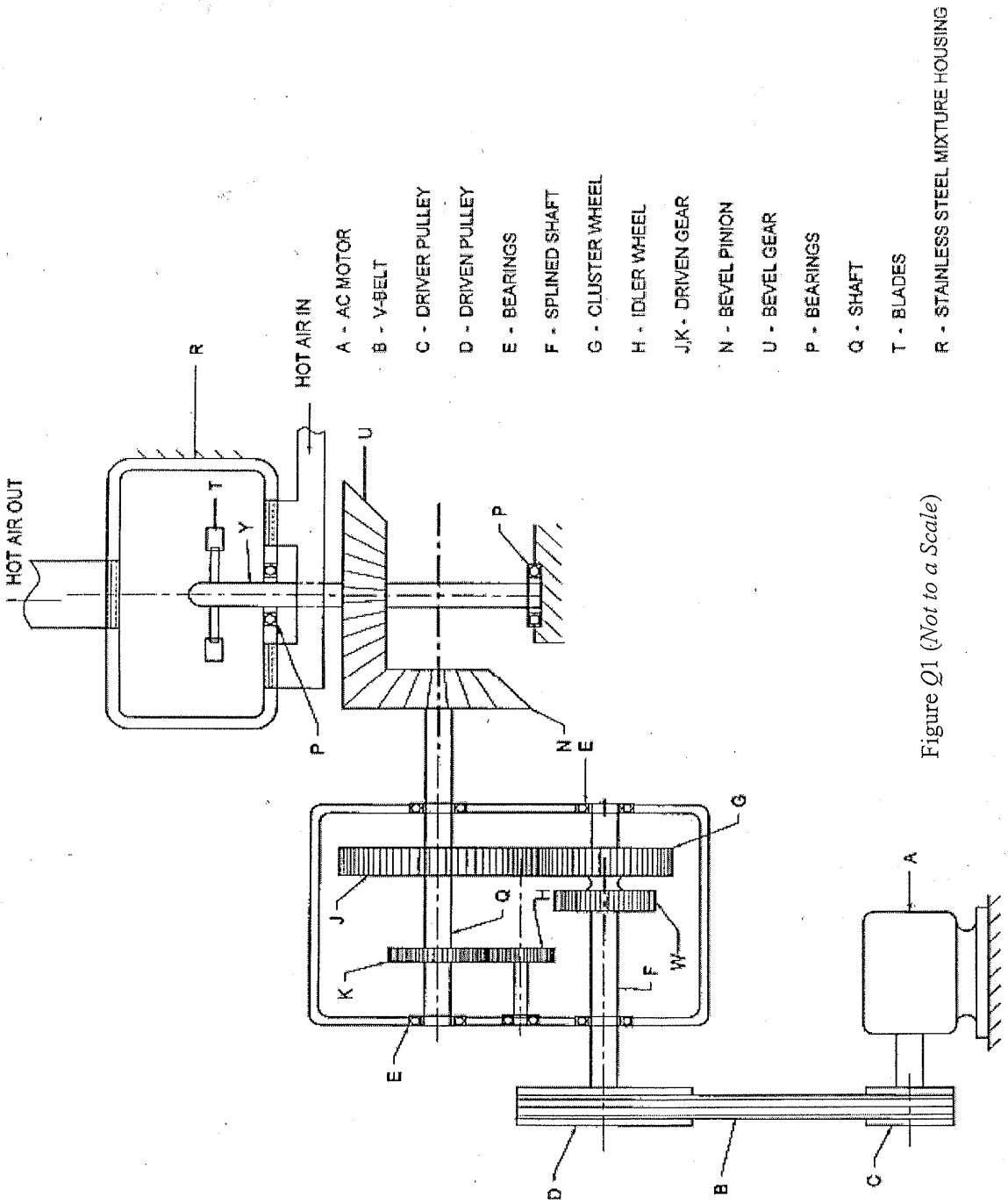

Figure *Q1* (*Not to a Scale*)

Ceylon Mills produces a variety of food items and consumable products, with one of their main offerings being coffee powder. The process begins by pre-heating coffee beans to a specific temperature, followed by grinding them into a powdered form using a grinder. Ceylon Mills' engineers have designed a mechanical system, as illustrated in Figure *Q*1, for the pre-heating of coffee beans. In this system, raw coffee beans are introduced into a cylindrical container (***R***), where hot air is supplied from the bottom to heat the beans. After heat is transferred to the beans, air is then evacuated through a duct-fan system located at the top of the container. The rotor, ensuring uniform processing, facilitates continuous agitation of the coffee beans inside the cylindrical container. Loading and unloading mechanisms for coffee beans are not depicted in Figure *Q*1. Additional details regarding the container and agitator blade arrangement can be found in Figure *Q*2.

The cylindrical container ***R***, into which the raw coffee beans are loaded, is made of stainless steel. The coffee beans are mixed by the rotating agitator (***T***). The agitator rotates in both directions (clockwise and anticlockwise) from time to time, governed by a timer, to maintain the best mixing effect, while coffee beans are heated uniformly throughout. V-belt drive consisting of Pulley ***C*** on the motor shaft and the pulley ***D*** on the gearbox input shaft transmits power through the gear train mounted inside the gear enclosure. The horizontal splined shaft ***F***, on which the cluster wheel ***G*** and ***W*** could be axially moved, is supported by two identical rolling element bearings ***E***. The cluster wheel has two wheel-segments ***G*** and ***W***. The shaft ***Q***, which carries the wheels ***J***, ***K*** and ***N*** is also supported by another pair of rolling element bearings. The pair of bevel gears ***N*** and ***U*** changes the vector direction of rotation by 90^0. The direction of rotation of the blade when the wheel segment ***G*** is in contact with wheel ***J***, is opposite to that when the segment ***W*** is in contact with ***H*** through ***K***. The shaft ***Y***, which is an integral part of the bevel gear ***U*** and whose axis is vertical, holds the agitator in position with the support of two suitable rolling element bearings (***P***). The container is firmly held to the machine frame to constrain the lateral movements of the shaft. The wheels ***G***, ***J***, ***Q***, ***H*** are enclosed in a gearbox.

Answer the following questions as if you were the designer of this machine.

1. From looking at the sketch what are the drawbacks of the proposed design? Also, recommend any improvements to the proposed design to achieve the objective more effectively. *[5 marks]*

For the given configuration,

2. Estimate the power required to drive the agitator. *[6 marks]*

3. Select a suitable motor and specify the power rating and speed, considering the pair of bevel gears to have a speed ratio in the range of 1 to 2. *[5 marks]*

4. Design a suitable V belt drive system. *[8 marks]*

5. Design the pair of spur gear wheels ***G*** and ***J*** selecting a suitable material. *[8 marks]*

6. Determine the minimum diameter of the splined shaft (***F***). *[8 marks]*

7. Select a suitable key for the driven pulley. *[5 marks]*

8. Recommend a suitable pair of rolling-element bearings that support the splined shaft F within the gear enclosure. *[5 marks]*

The following information are provided in support of the design analysis. You may use them (or make your own choices) according to your design intent.

1. The dimensions of the blades, arm of the blades and the container are as given in Figure *Q*2.

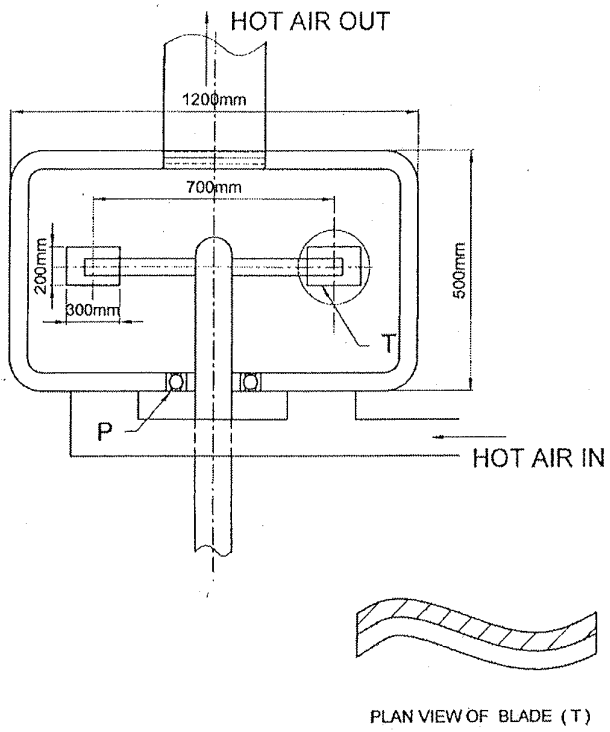

Figure *Q*2

These blades rotate at about 60 *rev/min*.

The amount of pressure applies to a blade is 20 kN/m^2 when the container is filled with the mixture to its maximum capacity.

Consider the projected area of a blade as 300 *mm* x 200 *mm*, on which the given pressure applies.

2. Axes of all the shafts lie on the same vertical plane.

3. Diameter of the splined shaft refers to its minor diameter and neglect the effects of splines when designing the shaft for strength.

4. Splined shaft experiences maximum state of stress when the pair of gears ***G*** and ***J*** transmits power.

5. Efficiencies are:

Bevel gears	92%
Spur wheels	94%
Belt drive	90%

6. Ratio of the pulley diameters are in the range of 0.5 to 3 and the center distance between pulleys can be in the range of 200 - 600 *mm*. This system is required to operate for over 10 hours a day continuously.

7. Pressure angle for any spur gear is 20°.

8. The velocity ratio of the spur gears can be selected between the range of 0.5 to 2.

9. Consider safety factors appropriately.

END OF QUESTION 1 AND PART A

PART B

Question 02

a. *Technological innovations have altered the course of history and greatly influenced further engineering developments.*
Explain this statement quoting appropriate examples. *[6 marks]*

b. i. *It is said that design/product cannot stand itself in isolation without its interfaces with social, economical (financial), and environmental factors.*
Do you agree with this statement? Clearly justify your answer. *[6 marks]*

ii. Taking a modern engineering product/s as an example/s, explain whether the designers have thought of the above-mentioned social, economic and environmental factors. *[5 marks]*

Question 3

a. For a square thread show that in the presence of a thrust collar, screwing-up torque (T_{su}) is given by, *[5 marks]*

$$T_{su} = F.\frac{d}{2}\left[\tan(\Psi + \phi) + \mu\frac{dm}{2}\right]$$

Where,

F -	axial load on screw	ψ -	helix angle
d -	pitch diameter of the thread	μ -	friction coefficient of nut on thrust collar
ϕ -	angle of friction	d_m -	mean diameter of the thrust collar

b. Figure *Q*3 shows a screw, which operates by application of a torque at the bottom end. The suitably designed guides prevent the rotation of the loaded nut of 50 *mm* height. The screw is a triple start trapezoidal thread, which the outer diameter is 48 mm and 8 *mm* pitch. The angle of the trapezoidal thread (2β) is 30°. The coefficient of friction of the treads is 0.15. Neglecting the friction of the ball bearing and the collar, find,

i. load that can be raised by a torque of 40 *Nm*. *[8 marks]*
ii. average bearing pressure between the screw and nut thread surface. *[4 marks]*

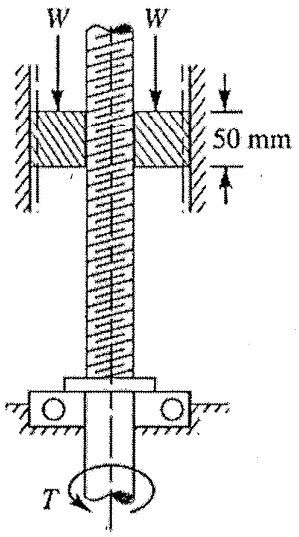

Figure Q3

Question 4

Figure *Q*4 shows a knuckle joint with dimensions associated with the solid rod of diameter (d).

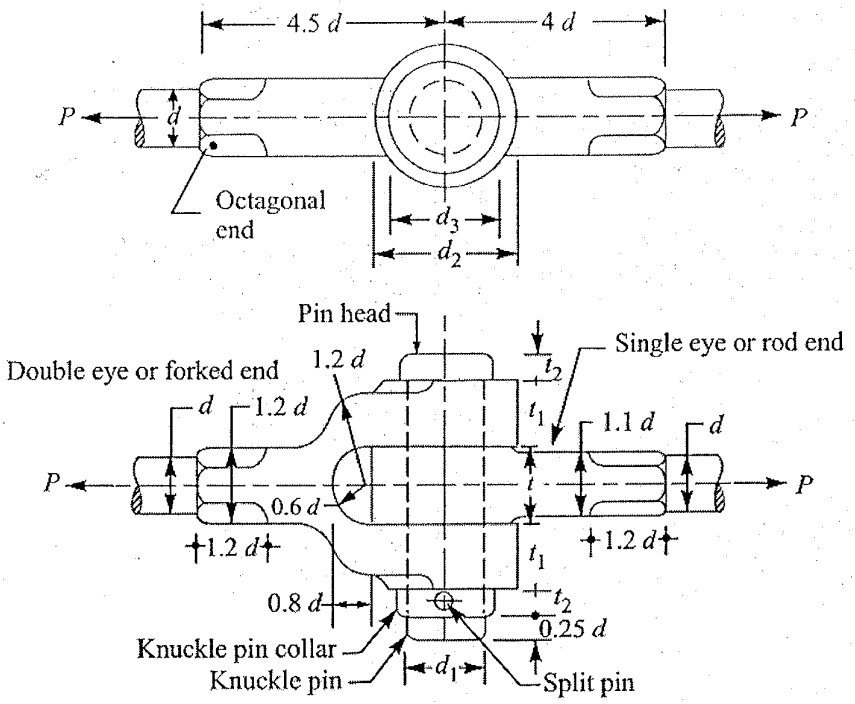

Figure *Q*4

If the design stresses are 75 *MPa* in tension, 60 *MPa* in shear and 150 *MPa* in crushing, design the knuckle joint to transfer 150 *kN* axial load considering,

i. failure of the solid rod in tension. *[3 marks]*

ii. failure of the knuckle pin in shear. *[2 marks]*

iii. failure of the single eye or rod end in tension. *[2 marks]*

iv. failure of the single eye or rod end in shearing. *[2 marks]*

v. failure of the single eye or rod end in crushing. *[2 marks]*

vi. failure of the forked end in tension. *[2 marks]*

vii. failure of the forked end in shearing. *[2 marks]*

viii. failure of the forked end in crushing. *[2 marks]*