

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



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	: 2024/25
Date	: 08 th March 2026
Time	: 0930 hrs. -1330 hrs.
Duration	: 4 hours

General Instructions:

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 Question 1 in PART A carry **50** marks. Whereas in PART B, Questions 2 and 3 each carry **17** marks, and Question 4 carries **16** marks.
3. **Attempt all parts in Question 1 in the given order**. Spend approximately 2 hours and 30 minutes to answer Question 1 and rest for Questions in PART B.
4. Wherever appropriate, use the documents 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 questions given should be underlined for the purpose of easy identification.

PART A**Question 1**

A Kids Park has a Vertical Merry-Go-Round, manually operated by a person as shown in Figure Q1(a). The owner of the Kids Park, who has knowledge in engineering, needs to motorize one of the merry-go-arounds, and he proposed a design which is shown in Figure Q1(b) (prepared not to scale). Assume that the owner hired you to complete the necessary calculations according to his design. The rotating structure is made of L-sectioned iron bars and GI pipes.

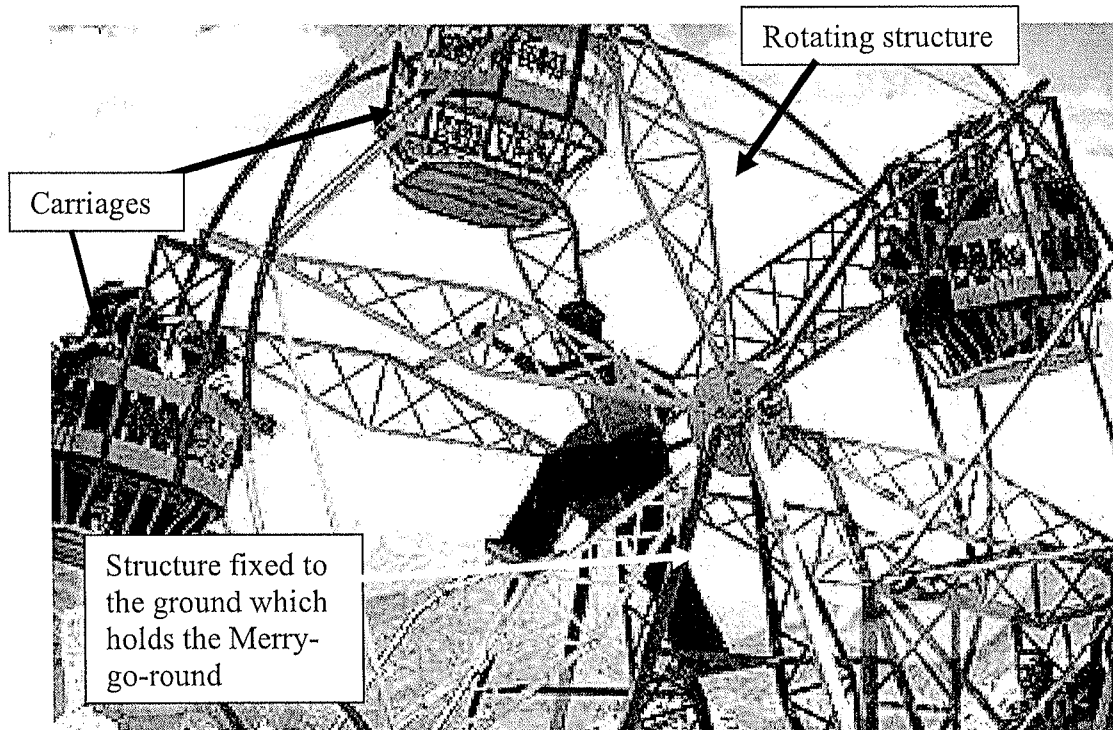


Figure Q1(a): Vertical Merry-Go-Round operated by a person

Main parameters and requirements of the proposed design are as follows.

Average weight of an Asian kid = 35 kg

Number of carriages = 6

Seating capacity = 4 kids per carriage

Diameter of the Merry-Go-Around (rotating structure) = 8 m

Total length of L-sectioned Iron bars needed for the rotating structure = 75 m

Weight of L-sectioned Iron bars = 3.5 kg/m

Total length of GI pipes needed for the rotating structure = 50 m

Weight of GI pipes = 5 kg/m

Maximum angular speed is around 6 rpm

Merry-Go-Round takes 6 seconds to attain this speed of 6 rpm from stationery.

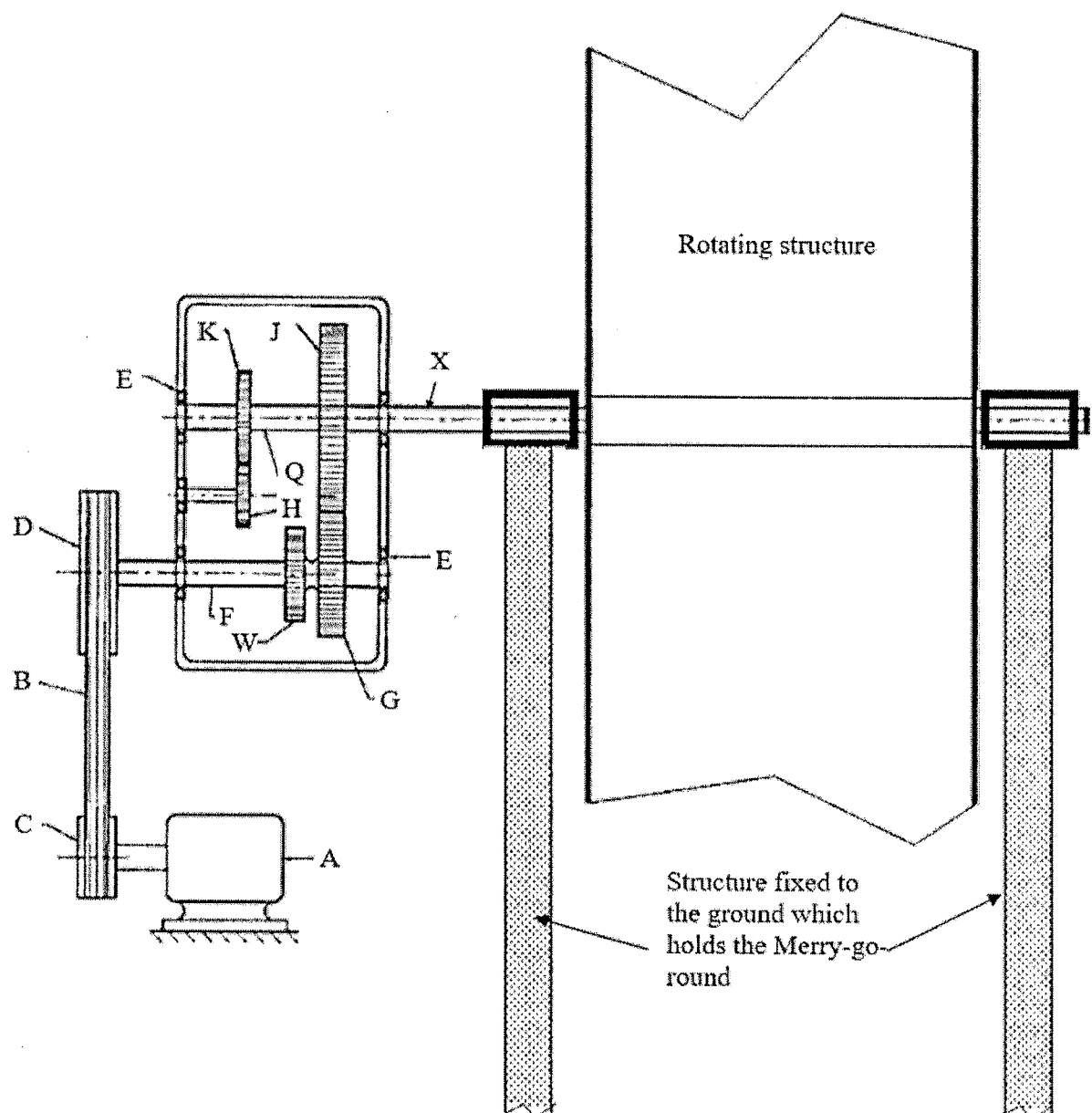


Figure Q1-b: Sketch of the proposed design (not to scale)

The Merry-Go-Around needs to be rotated in both directions (clockwise and anticlockwise). Pulley C on the motor shaft drives the pulley D and transmits power to the gear box by means of a suitable V-belt. 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 wheels J and K, is also supported by another pair of rolling element bearings. The direction of rotation of the rotating structure when the wheel segment G is in contact with wheel J, is opposite to that when the segment W is in contact with wheel K through H. The wheels G, J, Q, H, and W are enclosed in a gearbox. The output shaft of the gearbox X connects to the rotating structure of the Merry-Go-Around.

Answer the following questions as if you were the designer of this Merry-Go-Round.

1. Calculate the total weight of the Merry-Go-Round when it is operating at its fullest capacity (rotating structure with kids). [4 marks]
2. Calculate the power required to drive the Merry-Go-Round (rotating structure with kids).
Note: *You may assume that the Merry-Go-Round as a solid disk which the total weight is distributed uniformly.* [7 marks]
3. Select a suitable motor to drive the system. [3 marks]
Note: *A motor with low rated angular speed (rpm) is desirable. If not, you may have to use an additional belt drive or another suitable driving mechanism to obtain the required speed reduction.*
Power transmission efficiencies: Belt Drive - 90%, Gear Mesh points- 96% and Bearings- 96%.
4. Finalize the overall velocity ratio and decide the velocity ratios for the belt drive and for the gearbox. [3 marks]
5. Design the V-belt drive system. [8 marks]
Note: *If it is a two-stage reduction design only one reduction.*
6. Design the pair of spur gears **G** and **J**. [8 marks]
7. Suggest a suitable coupling to the mechanism and illustrate where you locate the coupling. [3 marks]
8. Design the input shaft **F**. [8 marks]
Note: *Diameter of the splined shaft refers to its minor diameter, and you may neglect the effects of splines when designing the shaft for strength. The shaft material has an allowable direct and shear stress of 50 MN/m² and 40 MN/m² respectively. Splined shaft experiences maximum state of stress when the pair of gears **G** and **J** transmit power. Take suitable safety factors.*
9. If the diameter of the output shaft **X** is equal to the diameter of the shaft **F** (calculated in part 8), select a suitable key to couple a gear wheel **J** to the output shaft. [3 marks]
10. Select suitable rolling element bearings for the input shaft **F**. [3 marks]

PART B**Question 2**

A rectangular plate shown in Figure Q2 made out of steel is 200 mm in length and 100 mm in depth. The plate is welded as a cantilever to a vertical column and supports a single concentrated load of 60 kN acting at the edge of the plate. Determine the size of the weld needed to hold the load. The maximum shear stress of the weld material is 140 MN/m². [17 marks]

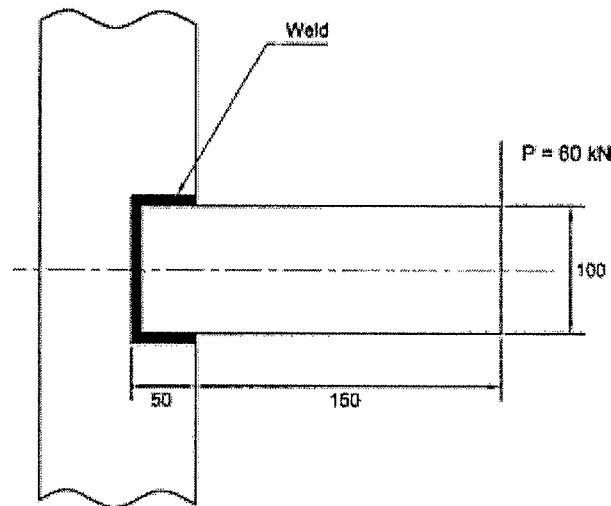


Figure Q2 (dimensions are in mm)

Note: You may use the following data if necessary.

Type of weld	Polar moment of inertia (J)	Section modulus (Z)
$x = \frac{l^2}{2l + b}$	$J = t \left[\frac{(b + 2l)^3}{12} - \frac{l^2 (b + l)^2}{b + 2l} \right]$	$Z = t \left(lb + \frac{b^2}{6} \right)$

Question 3

- a. For a square thread, show that in the presence of a thrust collar, the torque (T) required to lift an axial load (W) is given by,

$$T = W \left[\frac{d}{2} \tan(\alpha + \phi) + \mu R \right] \quad [5 \text{ marks}]$$

Where,
 W - axial load on screw
 d - mean diameter of the thread
 ϕ - angle of friction
 α - helix angle
 μ - friction coefficient of nut on thrust collar
 R - mean radius of the thrust collar

- b. A double start square threaded screw is used to support a vertical load of 18 kN. The mean diameter of the thread is 100 mm, and the pitch is 20 mm. The axial thrust on the screw is taken by a collar bearing of 250 mm outside and 100 mm inside diameter. Find the force required at the end of a lever, which is 400 mm long, to lift and lower the load. The coefficient of friction for the vertical screw and the nut is 0.5, and that for the collar bearing is 0.2. [12 marks]

Question 4

Answer four (4) of the following. You must use relevant equation/s and illustrations appropriately to support your answer. [4 marks for each part]

- i. *Sequential description of activities that typically follow in designing to obtain the most suitable end product is called the "Design Process".*
 Draw a flow diagram to illustrate the main steps of a design process and explain why it is necessary to have a properly defined design process.

- ii. What is 'Interchangeability in mass production'?

- iii. *It is said that more power could be transmitted by a V-belt drive than by a Flat belt drive.*
 Prove the above statement clearly.

- iv. Write a short note on fatigue failures of engineering components.

Note: Your answer should explain,

- *the importance of investigating fatigue failures of engineering materials,*
- *causes of fatigue failures,*
- *evaluation of the fatigue endurance limit of a material experimentally.*

- v. *Due consideration should be given to Ergonomic factors when designing an engineering artifact.*

Quoting appropriate examples of engineering products, explain what you understand by Ergonomics.

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