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

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX4306 Design of Machine Elements**
Academic Year	: 2019/20
Date	: October 10, 2020
Time	: 0930 -1330hrs
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**. Answer the question (Question 1) in PART **A** which is **compulsory**, and any three out of five questions from **PART B.**

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 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.

9. Write the question numbers to which you have answered, on the cover page.

PART A

Question 1

A - AC MOTOR
B - V-BELT
C - DRIVER PULLEY
D - DRIVEN PULLEY
E - BEARINGS
F - SPLINED SHAFT
G - CLUSTER WHEEL
H - IDLER WHEEL
J,K - DRIVEN GEAR
N,U - BEVELED GEARS
Q - SHAFT
T - BLADES
R - BUCKET SHAFT
V - BUCKET
X - HINGED

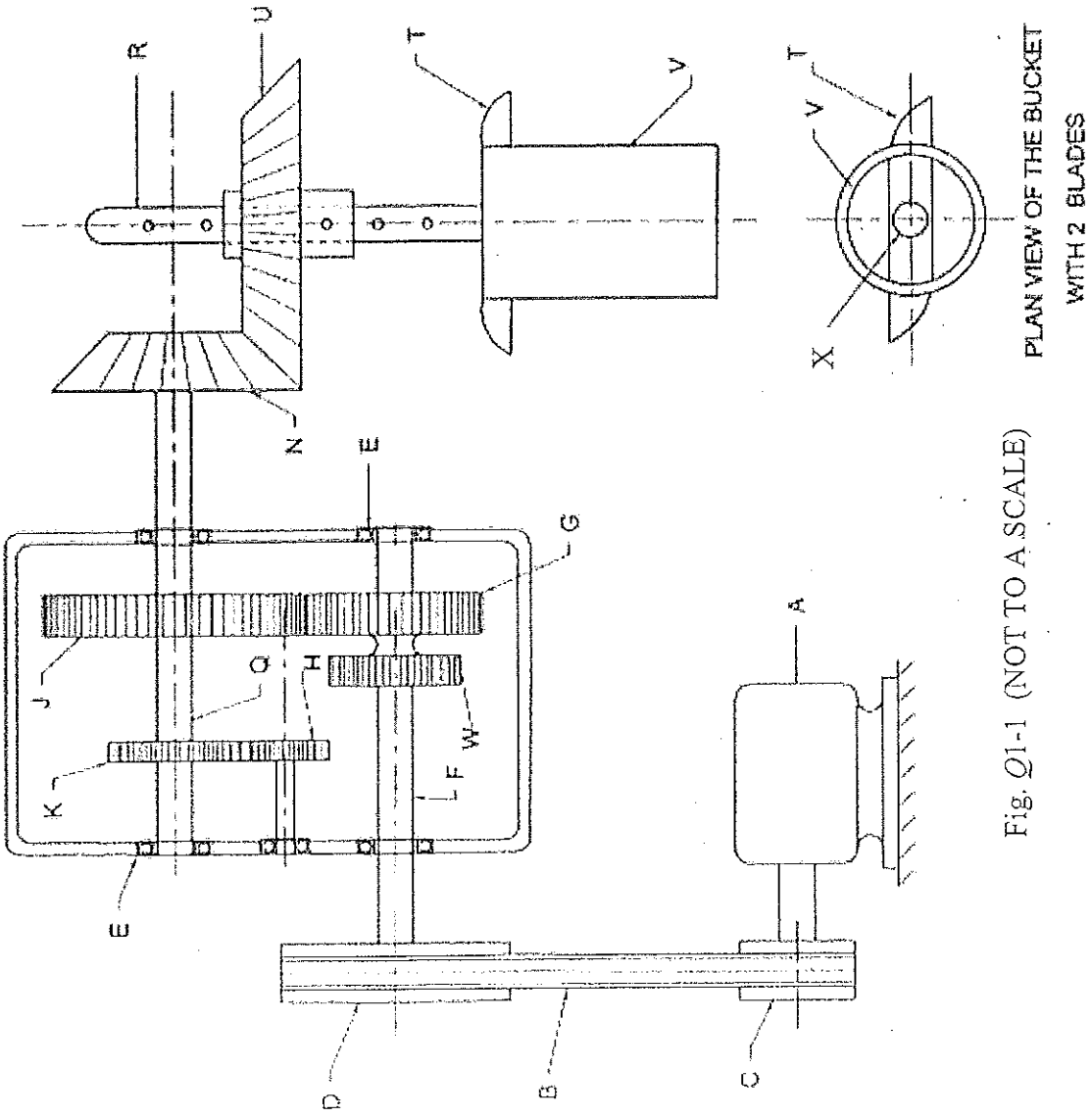

Fig. *Q*1-1 (NOT TO A SCALE)

A tentative design of a **well-digging-rig** to remove soil underneath the earth surface is given in Fig. $Q1$-1. The designer needs to confirm the accuracy of the machine components and invite suggestions for improvements. Fig.$Q1$-2 shows the digging bucket, which digs to extract soil (earth). The digging bucket consists of two blades located at 180 degrees apart at the periphery of the bucket and these two blades excavate and collect the soil into the bucket (refer Fig.$Q1$-3) as the bucket is driven vertically down gradually. Underneath the bucket it has a small set of cutters which does facing (surface cutting) of the earth (this arrangement can be visualized from Fig.$Q1$-6 and Fig.$Q1$-7), while the side cutting progresses with the pair of cutters located top of the bucket. The bucket collects all loose soil. Once the bucket is filled with soil, it is lifted to the earth surface and the soil is removed. The work cycle repeats until the it reaches the required depth of the well. **The bucket is connected to a shaft (bucket shaft) and extension shafts are been used to gradually increase the depth as digging progresses, to drive the bucket. Note that the lifting of the filled bucket and lowering the emptied bucket are been done by a separate mechanism which you need not to be considered.**

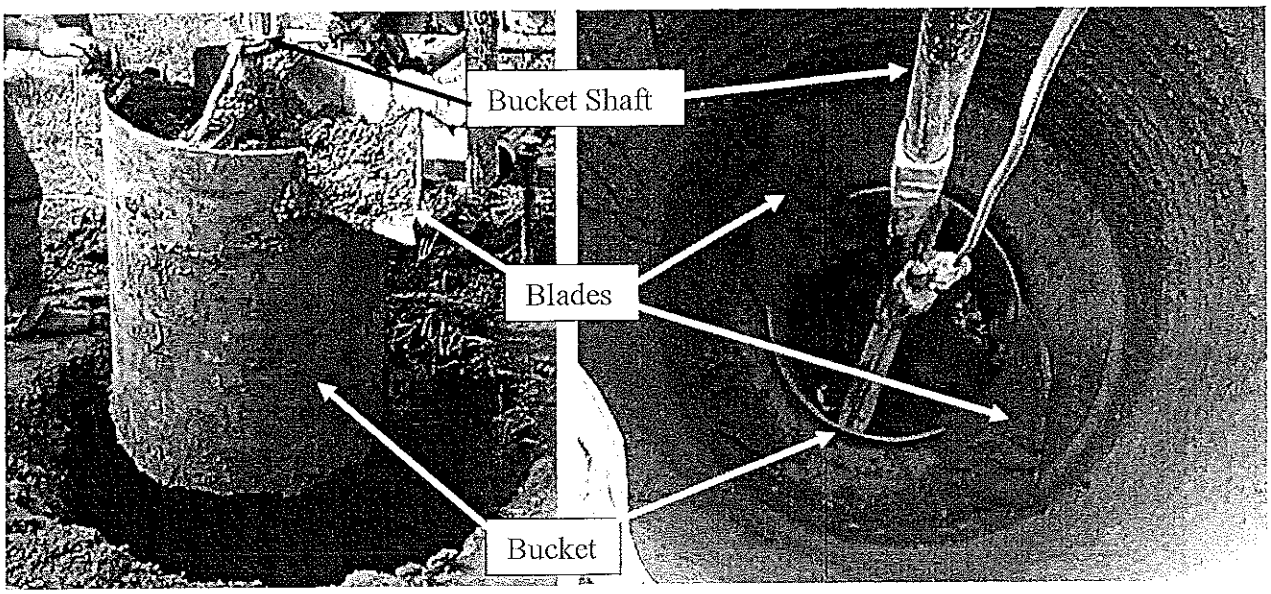

Fig.$Q1$-2

Fig.$Q1$-3

The bucket shaft R is driven by the motor A through the gear and belt mechanism shown in the Fig.$Q1$-1 and Fig.$Q1$-4. Of the belt drive system, driver pulley C on the motor shaft drives the driven pulley D by means of a suitable V–belt B. The horizontal splined shaft F mounted on two side-frames by two identical rolling element bearings E carries a cluster wheel having two-wheel segments G and W. The shaft Q, which caries the wheels J, K and N is mounted on the same side-frames through another pair of identical rolling element bearings. When the wheel segment G is in contact with the wheel J, power transmits to the pair of bevel gears (N and U) to rotate the vertical 'bucket shaft' to which the bucket is connected to. Whereas when W is in contact with the idler wheel H, power is transmitted through K to the same pair of bevel gears in order to reverse the direction of motion. As shown in the plan view of the shaft and the blade assembly, with a pair of blades are fitted diametrically and symmetrically opposite.

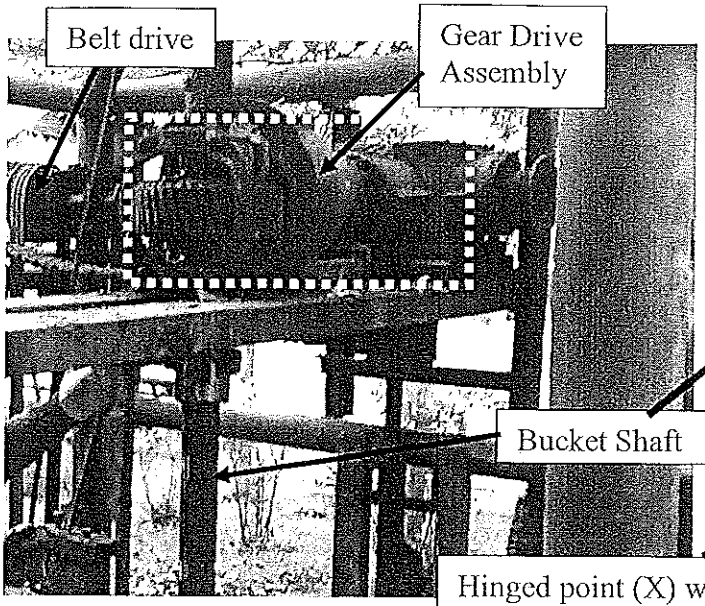

Fig.*Q*1-4

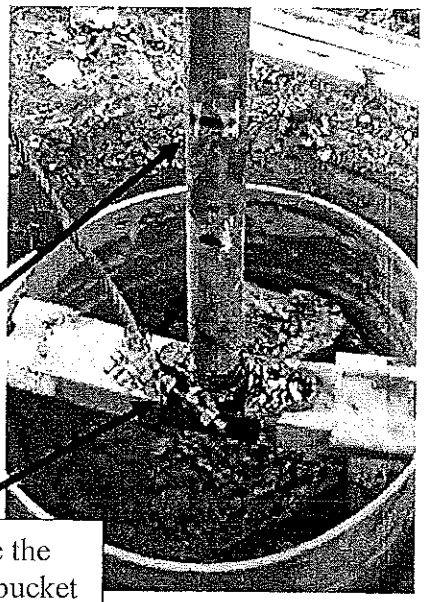

Fig.*Q*1-5

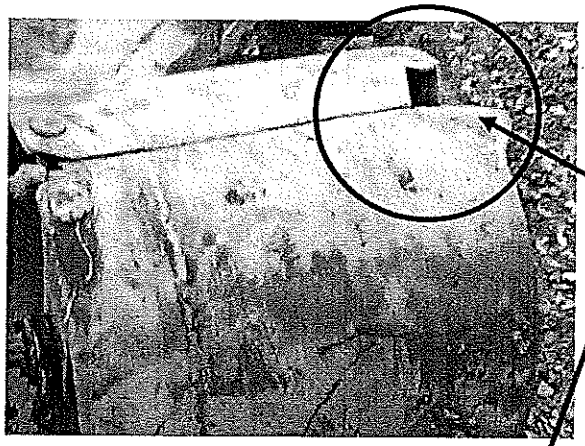

Fig.*Q*1-6

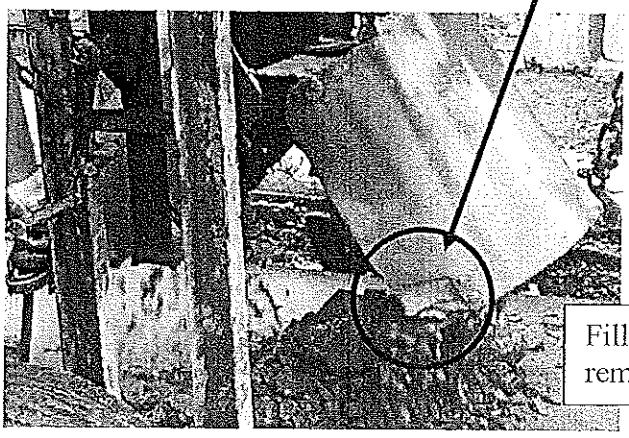

Fig.*Q*1-7

1. The Fig.$Q1$-8 shows the important dimensions of the bucket with blades.

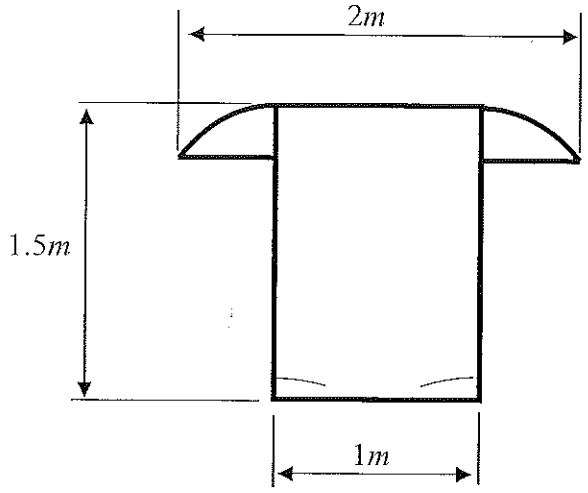

Fig.$Q1$-8

The maximum speed of the bucket is restricted to $20rev/min$.

When digging, one blade is subjected to a pressure of $20kN/m^2$ in horizontal direction. The bucket can contain $100kg$ of earth (soil) at its full capacity. The self-weight of the bucket with blades is $20kg$. A dredging force of $100N$ is applied on each blade at the start of cutting. The projected area of a top blade, normal to the direction of forward rotation $500cm^2$. The small blades underneath the buckets (facing blades) exerts a torque of $200Nm$ on the 'bucket shaft'. You may assume the torque exerts on to the 'bucket shaft' due to the friction force acting on the sides of the bucket as 25% of the torque induced by the facing blades.

2. Axis of all the shafts in the gear wheels and pulleys lie on a same vertical plane.

3. Efficiencies of the wheels can be considered as given below.

   Efficiency of bevel wheels = 94%
   Efficiency of spur wheels = 94%
   Efficiency of Belt drive = 90%

4. This system is required to operate for over 10 hours continuously a day.

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

6. For power transmission shafts shock and fatigue factors for bending and torsion are 2 and 1.5 respectively.

7. Select an appropriate shafting material from the given data sheets.

8. Assume that the splined shaft experiences maximum state of stress when the pair of wheels G and J transmits power.

9. Consider safety factors appropriately.

Answer the following questions.
(You may assume any missing details appropriately. Indicate the assumptions clearly)

1. Estimate the power required to operate the bucket at its full capacity. [*9 marks*]

2. Design a suitable V-belt drive system incorporating standard pulleys. [*9 marks*]

3. Design the pair of gears G and J. [*9 marks*]

4. Determine the minimum diameter of the splined shaft. [*8 marks*]

5. Select a suitable key for the driven pulley. [*4 marks*]

6. Select an appropriate pair of rolling element bearings to support the splined shaft. [*5 marks*]

7. Indicate the locations which couplings needed to be incorporated and state the most suitable type of coupling at each location. (*you may point out the locations with the proposed coupling on the Fig.Q1 and attached it to the answer script*). [*4 marks*]

8. List any modifications that you feel necessary to improve this drive mechanism. [*2 marks*]

END OF QUESTION 1 AND PART A

PART B

Question 2

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
d = pitch diameter of the thread
ϕ = angle of friction
ψ = helix angle
μ = friction coefficient of nut on thrust collar
d_m = mean diameter of the thrust collar

b. A 60 *mm* square threaded steel screw is used in a common screw jack, where a maximum load of 25 *kN* needed to be lifted. There are 2 threads per 24 *mm*. The body of the jack is made out of cast iron. The coefficient of friction on the thread is 0.2. The thrust collar of the top has an inside diameter of 40*mm* and an outer diameter of 70 *mm*. The coefficient of friction for the collar is 0.9. Determine,

(i) the efficiency of the screw and thrust collar. **[7 marks]**
(ii) the pull on the end of a 500 *mm* lever to operate this screw jack. **[5 marks]**

Question 03

a. State three (03) advantages and three (03) disadvantages of Welded joints over Riveted joints. **[4.5 marks]**

b. Fig.*Q3* shows the front and end elevation of a welded joint, where an angle is welded to a flange. The dimensions of the angle are 200 x 150 x 10 *mm* and it is subjected to an axial load of 200 *kN*. The allowable shear stress for the welding material is 75 N/mm^2. Determine the two weld lengths l_a and l_b, if the two weld lengths are such that the sum of the resisting moments of the weld about the gravity axis is zero. **[12.5 marks]**

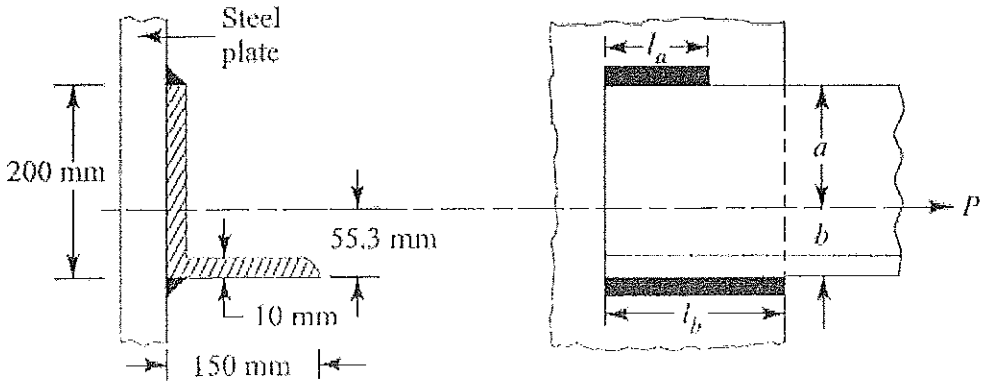

Fig.*Q3*

Question 04 **[17 marks]**

A motor is directly coupled to a gear box by means of a protective flange coupling which is shown in Fig.*Q*4. Both shafts which connect the motor and gear box are made of steel having allowable stress of $40MN/m^2$. Working stress in the bolts should not exceed $30MN/m^2$. The maximum torque is 25% greater than the mean torque. The coupling is made out of cast iron, with the design shear stress is $14MN/m^2$.

Design the coupling excluding keys, for the shafts transmitting $15kW$ at $200rpm$.

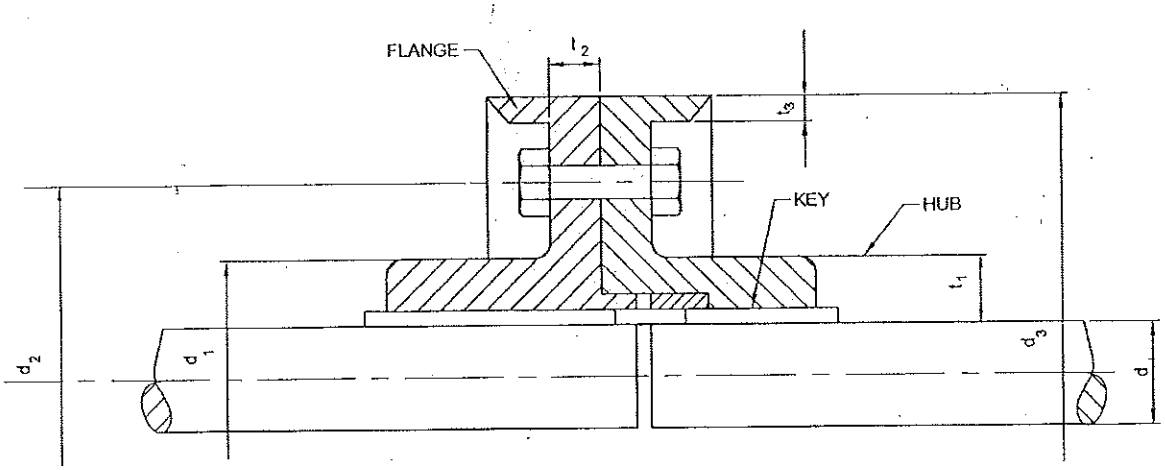

Fig.*Q*4: Half inverted plan of the flange coupling

Given that,

$d_1 = 2$ d (in *mm*)
length of the hub = 1.5 d
pitch circle diameter of bolts (d_2) = 3 d
Outer diameter of flange (d_3) = 4d
Flange thickness (t_2) = 0.5 d
Number of bolts = 3 (for, d<40 *mm*), 4 (for, 40 *mm*<d<100 *mm*), and 6(for,100 *mm*<d<180 *mm*)

Question 5

a. Briefly describes following:
   i. Positive clutch [*1.5 marks*]
   ii. Friction clutch [*1.5 marks*]

b. Write down two differences between a clutch and a coupling. [*3 marks*]

c. A single plate clutch, effective on both sides, is required to transmit 25 *kW* at 3,000 *rev/min.* Determine the outer and inner diameters of frictional surface if the coefficient of friction is 0.25, ratio of diameters is 1.25 and the maximum pressure is not to exceed 0.1 N/mm^2. Also, determine the axial trust to be provided by springs. Assume the condition of uniform wear. [*11 marks*]

Question 06

a. Answer the following, *(use examples and sketches to support your explanation)*.
   i. State what Residual stress is, and also explain how residual stresses are formed in engineering components. [*4 marks*]
   ii. Why it is necessary to consider stress concentration factor when designing engineering components. [*3 marks*]

b. A square shaped base plate is fixed at its four corners using nuts and bolts, which one fixation is shown in Fig.*Q*6. The bolt specification is *M20*. The plate rests on 4 washers of 22*mm* internal diameter and 50*mm* external diameter. Upper washers located between the nut and the base plate if of 22*mm* internal diameter and 44*mm* external diameter. With the self-weight total load on the base plate is 120*kN*.

   i. Calculate the stress on the lower washer is the nuts are not tightened. [*5 marks*]
   ii. If the nuts are tightened as such it induces a tension of 5*kN* at each bolt, calculate the stress in both upper and lower washers. [*5 marks*]

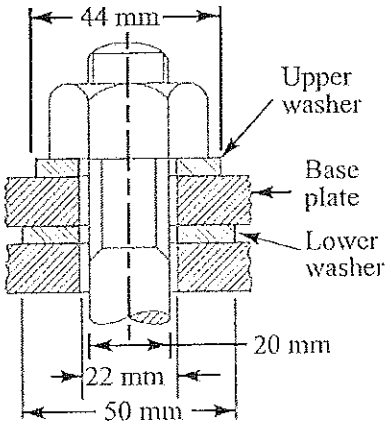

Fig.*Q*6