The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 2 MODULE, SPRING SEMESTER 2020-2021

DESIGN, MANUFACTURE AND PROJECT

Time allowed TWO hours plus 30 minutes upload period

Open-book take-home examination

Answer ALL questions

You must submit a single pdf document, produced in accordance with the guidelines provided on take-home examinations, that contains all of the work that you wish to have marked for this open-book examination. Your submission file should be named in the format '[Student ID]_MMME2044.pdf'.

Write your student ID number at the top of each page of your answers.

This work must be carried out and submitted as described on the Moodle page for this module. All work must be submitted via Moodle by the submission deadline. **Work submitted after the deadline will not be accepted without a valid EC.**

No academic enquiries will be answered by staff and no amendments to papers will be issued during the examination. If you believe there is a misprint, note it in your submission but answer the question as written.
Contact your Module Teams Channel or SS-AssessEng-UPE@exmail.nottingham.ac.uk for support as indicated in your training.

Plagiarism, false authorship and collusion are serious academic offences as defined in the University's Academic Misconduct Policy and will be dealt with in accordance with the University's Academic Misconduct Procedures. The work submitted by students must be their own and you must declare that you understand the meaning of academic misconduct and have not engaged in it during the production of your work.

1. Machine element 1

Bearings

(a) Which type of bearing would you choose for the following applications and briefly explain why in each case?

i) Bearings to support the main shafts of a manual gearbox of a passenger car

ii) Bearings to support the main shaft of a small gas turbine engine rotating at 25,000 rpm

iii) Bearings to support the axle of a wheelbarrow for gardening or construction work

[6]

(b) Figure Q1-1 shows a fan sub-assembly, which is driven by a pulley to power the fan rotating at required speed. The radial and axial forces as well as the torque load are indicated in the drawing. Briefly explain why this combination of bearings is chosen and how the bearings are located for proper function. [3]

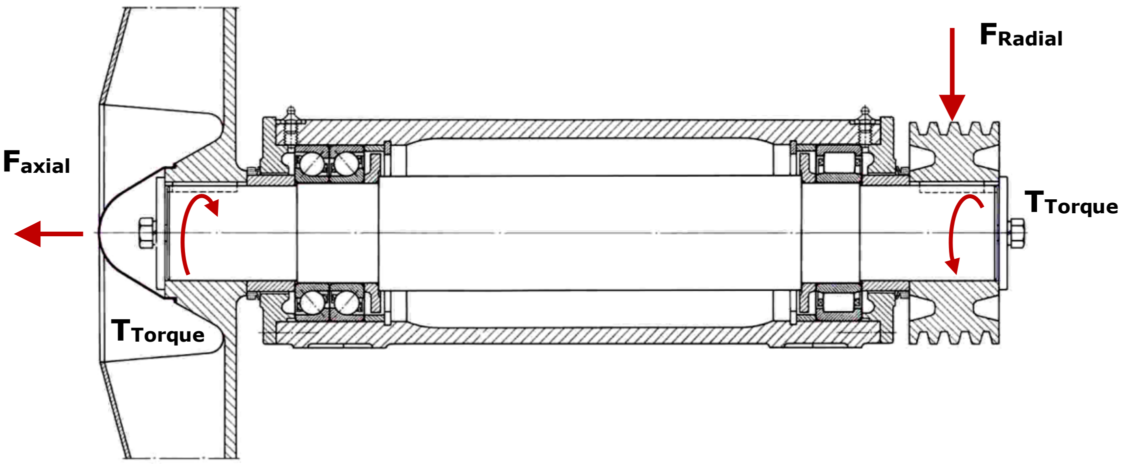

Figure Q1-1

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(c) Figure Q1-2 shows a pair of oil-impregnated bronze plain (sliding) bearings press fitted with a rotating pulley at a speed of n= 800 rpm. The pulley is subjected to a total radial load of $2F$ =1800 N. The axle is stationary. The dimensions of the plain bearings are shown in the figure. The diametrical clearance between the plain bearing and the axle is C =0.02 mm at the time of installation.

PV_{max} for oil lubricated bronze bearing is 2.5 MPa m/s and its maximum nominal bearing pressure is P_{max} = 5 MPa. The wear factor of the material is K =0.01x10-15 m^3/Nm.

i) Is the choice of the bearing size and material suitable for the operating conditions? Demonstrate your answer by calculation. [3]

ii) What is the predicted operation life of the bearing if the maximum allowable wear depth is y_{max}= 0.2 mm including the initial clearance? [3]

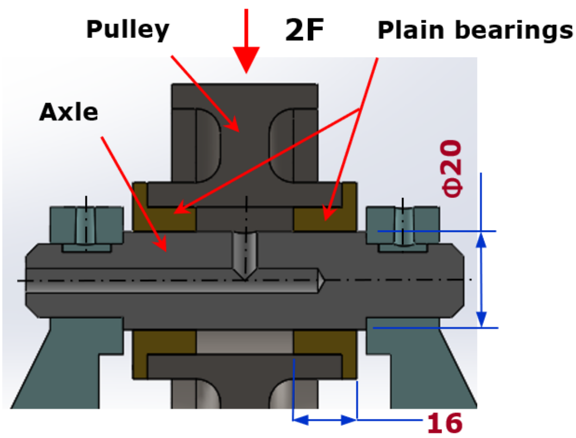

Figure Q1-2

You may find the following wear factor's equation useful:

$$K = \frac{W}{FVt}$$

where, K is wear factor (m^3/Nm)
W is wear volume (m^3)
F is bearing load (N)
V is the sliding velocity (m/s)
t is operating life (s)

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Brakes and clutches

(d) Figure Q1-3 shows FOUR design configurations of double shoe internal drum brakes with two actuation forces, *F*. The drum (or the rim) only rotates in the clockwise direction.

i) To achieve a maximum braking torque from the same amount of forces, *F*, which design configuration would you choose and explain briefly why? [2]

ii) Draw a free body diagram of your chosen design with both shoes and show the normal and friction forces as well as their moments applied to each of the shoes. [3]

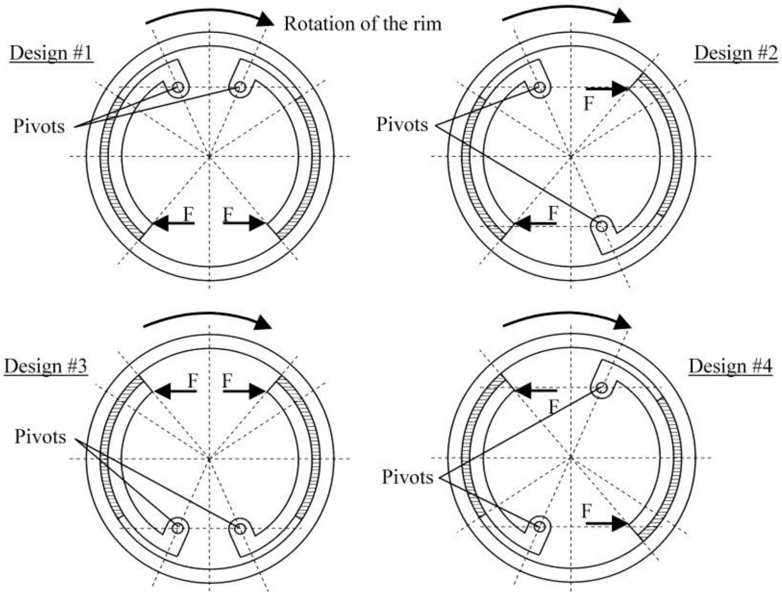

Figure Q1-3

2. Machine element 2

Bolted joints

(a) Four M6x1.0 bolts (9.8 to BS 3692) are used to assemble the cylinder head and crankcase of a two-stroke engine with a life of 10 years without scheduled service.

i) Name two feasible options that you may use to make the bolted joint a 'hard' joint of the engine assembly. [2]

ii) What amount of the tightening torque would you recommend to tighten each bolt in assembling the engine? [3]

You may find the following equations useful:

$F_i = 0.75A_s\sigma_P$ for non-permanent joint

$F_i = 0.9A_s\sigma_P$ for permanent joint

$T = KF_id$

where, F_i is the pre-tension load of bolt (N)
A_S is the tensile area of a bolt (A_s = 20.1 mm^2 for M6x1.0 bolts)
σ_P is proof strength of bolt (MPa)
T is the tightening torque (Nm)
K is torque coefficient (K = 0.2 is used for most cases)
d is the nominal bolt diameter (mm)

Linkage mechanisms

(b) Figure Q2-1 shows a schematic of a retractable landing gear of aircraft. Its retraction mechanism is a 4 bar linkage (O_1ABO_2) actuated by a hydraulic cylinder D pivoted at E.

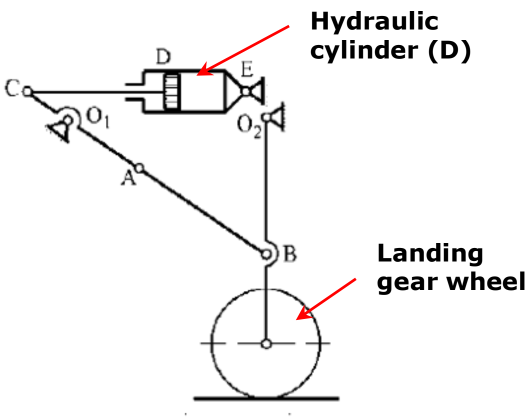

Figure Q2-1

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i) Use Gruebler's equation, calculate the numbers of DoF (Degree of Freedom) of the landing gear without considering the joint of the wheel. [3]

ii) The dimensions of the 4 bar linkage (O_1ABO_2) are measured as O_1O_2 = 650 mm, O_1A = 275 mm, AB = 500 mm and O_2B = 450 mm. Use Grashof condition to determine the specific type of this linkage. [3]

You may find the Gruebler's equation useful:

$$M = 3(L-1) - 2J$$

where, M is degree of freedom (DoF)
L is number of links
J is number of joints

Gears

(c) Figure Q2-2a) and b) shows a Solidworks assembly model and schematic of the gearbox for an offshore wind turbine. The low speed rotor drives the Arm (planetary carrier) of a planetary gear stage. The internal Ring gear (3) is part of the gearbox casing (i.e., ω_3=0). The Sun gear (1) of the planetary gear stage drives a two parallel gear stages (intermediate and high speed stages). Pinion (7) of the high speed stage is connected to the generator. The numbers of teeth of the gears are N_1=21, N_2=39, N_3=99, N_4=82, N_5=23, N_6=88 and N_7=22.

i) Use ONE sentence to explain a key functional requirement of a wind turbine gearbox in consideration of the normal range of speeds of the input rotor and output to the generator. [2]

ii) Calculate the gear ratios of each stage of the gearbox, i.e. [5]
- the planetary stage (Sun 1, Planet 2, Ring 3 and the Arm),
- the intermediate speed stage (Pinion 5 and Gear 4),
- the high speed stage (Pinion 7 and Gear 6).

iii) If the rotor rotates at a low speed of 20 rpm, what is the speed of the high speed shaft (Pinion 7) connected to the generator? [2]

You may find the following gear ratio equations useful:

$$Z = \frac{\omega_P}{\omega_G} = \frac{N_G}{N_P}$$

where, ω_P is the rotating speed of the pinion
ω_G is the rotating speed of the gear
N_P and N_G are teeth numbers of the pinion and gear, respectively

$$Z = \frac{\omega_F - \omega_A}{\omega_L - \omega_A} = \pm \frac{product\ of\ number\ of\ teeth\ on\ wheels}{product\ of\ number\ of\ teeth\ on\ pinions}$$

where, ω_F is the rotating speed of the first (input) gear
ω_L is the rotating speed of the last (output) gear
ω_A is the rotating speed of the arm or planet carrier

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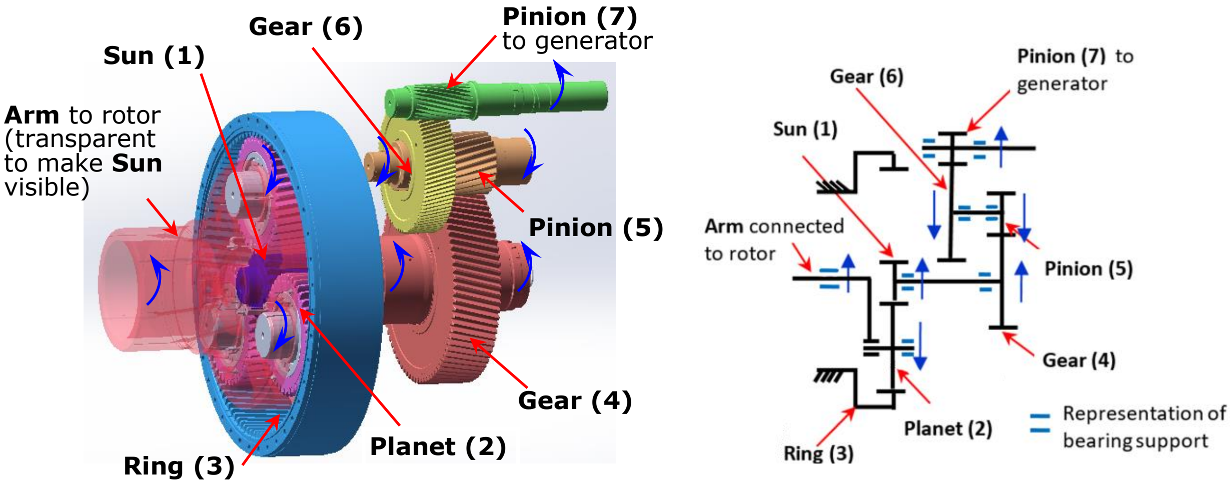

Figure Q2-2 a) and b

3. General Design Methods

For both parts of this question you should use the example products provided in Table Q3-1.

(a) **Design for sustainability:**
'Design for sustainability' considers the sustainability of a product across its lifecycle within the three sustainability domains: Economic, Social and Environmental. There is a sustainability evaluation method called 'The Six Rs' which asks the designer to evaluate six possible changes to a product to improve its sustainability.
Using the example products provided in Table Q3-1 you should provide one example of each of the six Rs. For each example you should clearly identify the R, clearly state the changes that you would make to the product, and clearly state how those changes would improve its Economic, Social or Environmental sustainability.

You may use an example product to illustrate more than one of the Rs. [12]
[up to 2 marks available for each 'R']

(b) **Design for inclusivity:**
'Design for inclusivity' considers the accessibility and equitable use of products across a population. It considers many aspects of inclusivity from physical and mental capability to a products presentation and any possible stigmatization from its use. You have been introduced to 7 principles/objectives for evaluating inclusivity in a products design.
Choose any <u>FOUR</u> of the principles/objectives of inclusive design and using the example products provided in Table Q3-1 you should provide an example of poor inclusivity in design.
For each example you should clearly identify the principle/objective that you are evaluating, state how the current design limits inclusivity and how your proposed change would correct that.
You may use an example product to illustrate more than one principle/objective. [8]
[up to 2 marks available for each example, max. FOUR examples]

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Table Q3-1

Product	Description
Personal Electric Bike	• Produced in China, sold exclusively in the UK. • Expensive to own. • Heavily marketed towards younger users. • Fixed positions for controls. • Product lifetime ~10 yrs.
Low budget student laptop	• Produced in China, sold worldwide. • Not designed to be upgradable. • Difficult to take apart. • Underpowered for activities such a gaming & streaming. • Product lifetime ~3yrs.
'Designer' chrome desk lamp.	• Produced in France, sold worldwide. • Metal casing with all chrome finish (hexavalent chrome process). • Heavy construction with weighted base make it costly to ship. • Switch is positioned out of sight at the back of the lamps base. • No visual indicator of whether the switch it in the on or off position, other than the bulb itself.
Jar of unground coffee beans	• Coffee grown and packaged in Brazil, sold worldwide. • Sold in glass jar with a tight sealing steel lid. • Materials in can account for 20% of energy input. • Product lifetime is expected to be very short, i.e. a disposable item, but packaging is non-biodegradable.
Front loading washing machine	• Produced in Hungary, sold worldwide. • Touchscreen control panel. Setting a cycle requires the user to go through several steps. If they make an error they have to start again. • Controller is known to be prone to electrical faults. • Door mechanism is low. Cannot be loaded or unloaded from standing position. • EPC B Energy rating. • Product lifetime ~5yrs.

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