ID Number _____

THE GEORGE W. WOODRUFF SCHOOL OF MECHANICAL ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY

DESIGN QUALIFIER

SPRING 2016

PART I. WRITTEN EXAMINATION

We are interested in learning what you know and your ability to reason in the formulation and solution of design problems.

If you find any part of this exam confusing, please state your assumptions and rephrase the question and proceed.

Please read the entire exam first.

Questions I, IIA and IIB carry equal points.

Allocate your time carefully so that you cover all three parts that you are being examined on in these two questions, namely Methodology and Analysis.

PART II. ORAL EXAMINATION

Please arrive 30 minutes before the scheduled time for the oral exam. During this period we will give you a question to think about. The scope of the oral exam is as follows:

* provide an opportunity for you to state how design fits into your research activities;
* probe your understanding on the question that we posed to you in the preceding half hour.

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QUESTION I. – DESIGN METHODOLOGY

I.1 DESIGN PRINCIPLE

The location of cup-holders and ashtray on vehicle instrument panel can affect instrument panel appearance as well as cup-holder and ashtray functionality. Figure 1(a) shows the design of cup-holders and ashtray on the instrument panel for the GM Silverado 1999 Model-Year Pickup Truck. It is clearly shown in Figure 1(a) that when there are cups in the cup-holders, the ashtray cannot be pulled out far enough for use, since the cup at the right side occupies the ashtray free space.

Figure 1(a): 1999 Model-Year GM Silverado cup-holders and ashtray on the instrument panel with cups in cup-holders

Figure 1(b) shows the cup-holder and ashtray design of Ford F150 1999 Model Year Pickup Truck with both cup-holders and ashtray in open position.

Figure 1(b): 1999 Model-Year Ford F150 cup-holders and ashtray on the instrument panel

You are required to use formal design principles (e.g., axiomatic design theory) to illustrate why the cup-holders and ashtray design of Ford F-150 is better than that of GM Silverado.

(5 points)

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I.2 DESIGN THEORY

Product family design aims to take advantage of common component parts to provide product variety while achieving economics of scale. Commonality analysis suggests itself to be a critical issue of a product family that consists of multiple product variants. Figure 2 shows a product family comprising 3 product variants (P1, P2, and P3) and the structure of each product variant that is characterized by the respective bill-of-materials (BOM). Each node of the BOM structure stands for a distinct component part that is identified by its part number (e.g., d1, d2, etc.) Also shown in a BOM structure is the respective quantity per (e.g., x1, x3, etc.) for each component part.

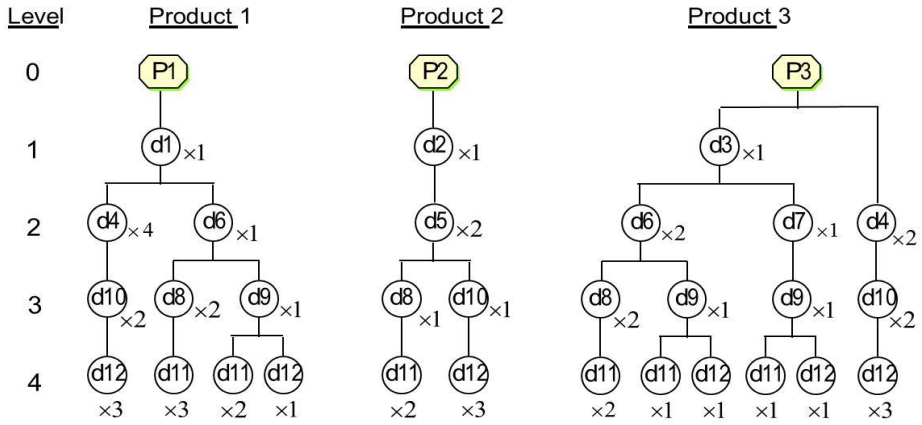

Figure 2: The BOM structures of three product variants in one product family

You are required to develop a quantitative measure to access the degree of commonality for this product family design.

(5 points)

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Question IIA. (10 points)

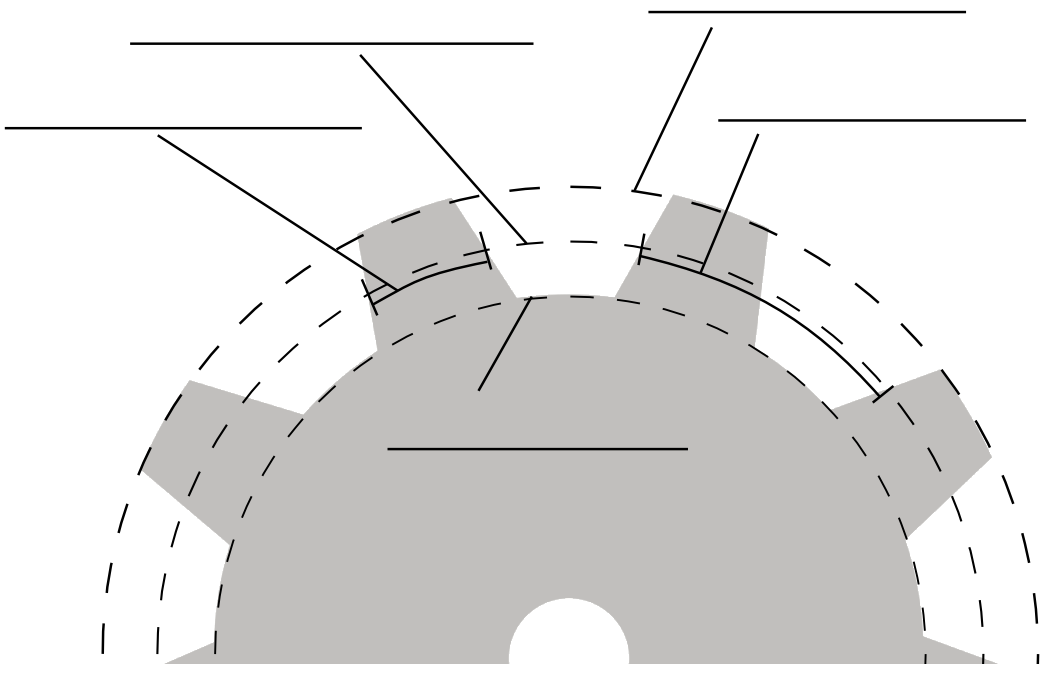
1. What is the defining characteristic of a planetary gear train? (1 point).

2. Other than providing a film between the rolling and sliding surfaces in a bearing, describe one purpose of antifriction-bearing lubricant (1 point).

3. Assign either "oil" or "grease" as the type of lubrication to the following conditions for bearing lubrication (1 point).

    a. The operating temperature is below 200^{o}F. _____
    b. The speed of operation is high. _____
    c. Operation for long periods without attention is desired. _____
    d. Unusual protection is required from the entrance of foreign matter. _____

4. Label each of the five features of the gear geometry below (2 points).



5. Why should a washer always be used under a bolt head? (1 point)

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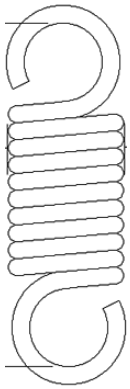
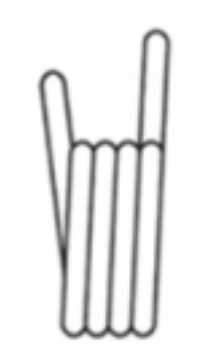
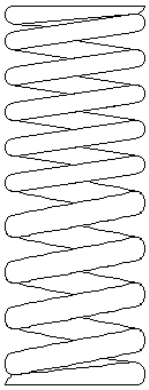
6. Rank the materials below from highest (1) to lowest (4) Young's Modulus value. (2 points)

_____Diamond _____Aluminum ____Rubber _____Steel

7. What are the intended loading types for the three springs shown below? (2 points)







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IIB – Pressure Reducing Valve (10 points)

In Figure 1, a pressure reducing valve I shown that is connected into a water line coming from a water pump. The incoming pressure through the pump may vary from 250 kPa to 1200 kPa.

There are two separate airtight compartments in the valve, divided by a flexible diaphragm. In the upper compartment is a spring, which may be set to provide a given reduced pressure by means of the adjusting screw. The cover cap over the adjusting screw is secured by a padlock to prevent tampering.

The lower compartment is further divided into two separate spaces by a small piston attached to the middle of the stem, the piston sliding in a cylinder (Figure 1). The stem has whole drilled through from its lower end to just above the piston, where a port leads out into the space above the piston. Figure 1 shows how the feed water bears both upward against the piston and downward against the valve disk, thus balancing. The water in the outlet side of the valve also flows up through the stem and bears against the diaphragm, keeping the spring in balance at its set pressure

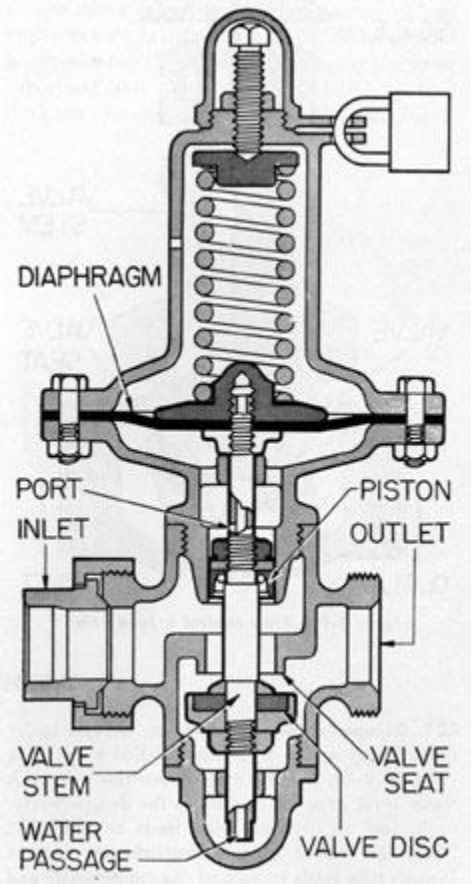

Figure 1 – Pressure Reducing Valve.

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The area of the diaphragm on which the water pressure acts is 950 mm^2. The spring shown in Figure 1 has the following dimensions: total number of coils N_{total} = 12, free length Lf = 80 mm, wire diameter d = 5 mm, mean coil diameter D = 25 mm. The spring is made of A228 music wire with a modulus of rigidity G=79.3 Gpa. The modulus of elasticity E for carbon steel is 207 GPa. The modulus of elasticity E for cast iron is 100 GPa. The modulus of elasticity E for the flexible diaphragm material is 0.2 GPA.

a) What is the factor of safety for the pressure on the diaphragm at which all coils of the spring in the pressure valve will be touching? (4 points)

As shown in Figure 1, the steam inlet contains a top cover housing, which is made of carbon steel. The plan is to bolt this cover to the main body of the pressure reducer by four fully threaded carbon steel M12 bolts and nuts. Assume that the total load on the joint is 1,500 N and that the tensile stress area of an M12 bolt is 84 mm^2. The thickness of the diaphragm is 2 mm. The thicknesses of the steel members in the bolted joint are 10 mm each.

b) If the joint constant C = 0.2, what is the stiffness of the members in the grip of the bolted joint? (2 points)

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c) Calculate the difference between the stiffness of the steel flanges and the flexible diaphragm. Assume that the flange used to clamp the top cover to the main body is very narrow and the bolts are very close to the flange edge. (3 points)

d) Assuming that the total load on a roller bearing is 1000 N and the bearing's basic load rating is 20,000 N, what is the L_{10} life of the bearing? (1 point)

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