TECHNICAL UNIVERSITY OF MOMBASA

Faculty of Engineering and Technology
Department of Mechanical & Automotive Engineering
SPECIAL/SUPPLEMENTARY EXAMINATION FOR:
BSc. Mechanical Engineering
EMG 2306 : INTRODUCTION TO ENGINEERING DESIGN
END OF SEMESTER EXAMINATION (SCHOOL BASED)
SERIES: DECEMBER2017
TIME: 2 HOURS
DATE: Pick Date**Dec2017**

<u>Instruction to Candidates:</u>

You should have the following for this examination

- *Answer booklet*
- *Non-Programmable scientific calculator*

This paper consists of **FIVE** questions.
Question **ONE** is **COMPULSORY**
Attempt any other **TWO** questions.
Maximum marks for each part of a question are as shown.
Do not write on the question paper.
Mobile phones are not allowed in the examination room.

Question ONE (COMPULSORY: 30 Marks)

THE TITANIC

The Titanic began its maiden voyage to New York just before noon on April 10, 1912, from Southampton, England. Two days later at 11.40 p.m., Greenland time, it struck an iceberg that was three to six times larger than its own mass, damaging the hull so that the six forward compartments were ruptured. The flooding of these compartments was sufficient to cause the ship to sink within two hours and 40 minutes, with a loss of more than 1,500 lives. The scope of the tragedy, coupled with detailed historical record, have fueled endless fascination with the ship and debate over the reasons as to why it did in fact sink. A frequently cited culprit is the quality of the steel used in the ship`s construction. Analysis of the hull steel recovered from the ship`s wreckage provides a clearer view of the issue.

THE CONSTRUCTION

In the early 20th century, ships were constructed using wrought-iron rivets to attach steel plates to each other or to a steel frame. The frame itself was held together by similar rivets. Holes were punched at appropriate sites in the steel frame members and plates for the insertion of the rivets. Each rivet was heated well into the austenite temperature region, inserted in the mated holes of the respective plates or frame members, and hydraulically squeezed to fill the holes and form a head. Three million rivets were used in the construction of the ship.

THE VOYAGE

On the moonless night of April 14, the ocean was very calm and still. At 11.40 p.m., Greenland time, the lookouts in the crow`s nest sighted an iceberg immediately ahead of the ship; the bridge was alerted. The duty officer ordered the ship hard to port and the engines reversed. In about 40 seconds, as the Titanic was beginning to respond to the change in course, it collided with an iceberg estimated to have a gross weight of 150,000 – 300,000 tons. The iceberg struck the Titanic near the bow on the starboard (right) side about 4 m above the keel. During the next 10 seconds, the iceberg raked the starboard side of the ship`s hull for about 100 m, damaging the hull plates and popping rivets, thus opening the first six of the 16 watertight compartments formed by the transverse bulkheads. Inspection shortly after the collision by Captain Edward Smith and Thomas Andrews, a managing director and chief designer for Harland and Wolff and chief designer of the Titanic, revealed that the ship had been fatally damaged and could not survive long. At 2.20 a.m., April 15, 1912, the Titanic sank with the loss of more than 1,500 lives.

Initial studies of the sinking proposed that a continuous gash in the hull 100 m in length was created by the impact with the iceberg. More recent studies indicate that discontinuous damage occurred along the 100 m length of the hull. After the sinking, Edward Wilding, design engineer for Harland and Wolff, estimated that the collision had created openings in the hull totaling 1.115 m^2, based on the reports of the rate of flooding given by the survivors. This damage to the hull was sufficient to cause the ship to sink.

At the time of the accident, there was disagreement among the survivors as to whether the Titanic broke into two parts as it sank or whether it sank intact. On September 1, 1985, Robert Ballard found the Titanic in 3,700 m of water on the ocean floor. The ship had broken into two major sections, which are about 600 m apart. Between these two sections is a debris field containing broken pieces of steel hull and bulkhead plates, rivets that had been pulled out, dining room cutlery and chinaware, cabin and deck furniture, and other debris.

The only items to survive at the site are those made of metals or ceramics. All items made from organic materials have long since been consumed by scavengers, except for items made from leather such as shoes, suitcases, and mail sacks; tanning made leather unpalatable for the scavengers. The contents of the leather suitcases and mail sacks, having been protected have been retrieved and restored.

Table I. The Composition of Steels from the Titanic, a Lock Gate, and ASTM A36 Steel

	C	Mn	P	S	Si	Cu	O	N	MnS: Ratio
Titanic Hull Plate	0.21	0.47	0.045	0.069	0.017	0.024	0.013	0.0035	6.8:1
Lock Gate*	0.25	0.52	0.01	0.03	0.02	-	0.018	0.0035	17.3:1
ASTM A36	0.20	0.55	0.012	0.037	0.007	0.01	0.079	0.0032	14.9:1

*Steel from a lock gate at the Chittenden ship lock between Lake Washington and Puget Sound, Seattle, Washington.

THE STEEL

During an expedition to the wreckage in the North Atlantic on August 15, 1996, researchers brought back steel from the hull of the ship for metallurgical analysis. After the steel was received at the University of Missouri-Rolla, the first step was to determine its composition. The chemical analysis of the steel from the hull is given in Table I. The first item noted is the very low nitrogen content. This indicates that the steel was not made by the Bessemer process; such steel would have a high nitrogen content that would have made it very brittle, particularly at low temperatures. In the early 20th century, the only other method for making structural steel was the open hearth process. The fairly high oxygen and low silicon content means that the steel has only been partially deoxidized, yielding a semikilled steel. The Phosphorus content is slightly higher than normal, while the sulfur content is quite high, accompanied by low manganese content. This yielded a Mn:S ratio of 6.8:1 – a very low ratio by modern standards. The presence of relatively high amounts of phosphorous, oxygen, and sulfur has a tendency to embrittle the steel at low temperatures.

Included in Table I are the compositions of two other steels: steel used to construct lock gates at the Chittenden Ship Lock between Lake Washington and Puget Sound at Seattle, Washington, and the composition of modern steel, ASTM A36. The ship lock was built around 1912, making the steel about the same age as the steel from the Titanic.

Comparing the composition of the Titanic steel and ASTM A36 steel shows that the modern steel has a higher manganese content and lower sulfur content, yielding a higher Mn:S ratio that reduced the ductile-brittle transition temperature substantially. In addition, ASTM A36 steel has a substantially lower phosphorus content, which will also lower the ductile-brittle transition temperature.

CONCLUSIONS

The steel used in constructing the RMS Titanic was probably the best plain carbon ship plate available in the period of 1909 to 1911, but it would not be acceptable at the present time for any construction purposes and particularly not for ship construction. Whether a ship constructed of modern steel would have suffered as much damage as the Titanic in a similar accident seems problematic. Navigational aides exist now that did not exist in 1912; hence, icebergs would be sighted at a much greater distance, allowing more time for evasive action. If the Titanic had not collided with the iceberg, it could have had a career of more than 20 years.

<u>Required:</u>

You being a 3rd year design student are now tasked with re-designing the Titanic. Write your two page report to your engineering manager with the steps that you would undertake to accomplish your task and your recommendations towards the integrity of the new design. (30 Marks)

Question TWO (20 Marks)

a) People who follow procedures and processes with a blind allegiance and without using their brain to critically think and understand what they are doing, lose the benefit of applying their own creative ability to search for a better more elegant solution. Name and briefly explain five methods which stimulate creativity? (10 Marks)

b) Biologically inspired designs have served humanity over millions of years; explain how a young quacking duck attracts its mother and what are the main design factors in an innovation of an electronic toy device that can attract the same mother? (5 Marks)

c) The ability to compute separates the engineer from the technician. Engineering mathematics generates an insight (i.e., an intuitive understanding) into the behavior of physical things which cannot be attained in any other way and which is essential for inventive thinking i.e. the generation of new valuable ideas which will work. In the innovative design of a flying car, name and briefly explain five of the major functional considerations. (5 Marks)

Question THREE (20 Marks)

a) Briefly describe any eight factors that you would consider when designing a machine component. (8 Marks)
b) State four properties that materials for making a shaft should have (4 Marks)
c) State five requirements for a good shaft coupling (5 Marks)
d) State three common safety hazards of working machinery (3 Marks)

Question FOUR (20 Marks)

a) Discuss the four factors which govern the selection of materials for design consideration in machine components. (4 Marks)
b) What are the six advantages and four disadvantages of cast iron as an engineering material? (10 Marks)
c) What are alloy steels? (2 Marks)
d) State two advantages and two disadvantages of Aluminum alloys. (4 Marks)

Question FIVE (20 Marks)

a) A shaft is made to the dimension 40 mm ± 0.05. State the nominal dimension, the upper limit, the lower limit and the tolerance. (2 Marks)
b) Illustrate with sketches each of the following:
   i) Clearance fit (2 Marks)
   ii) Interference fit (2 Marks)
   iii) Transition fit (2 Marks)
c) For each of the following combinations, calculate the extremes of fit. Hence, state whether each fit is a clearance, interference or transition.

	Hole (mm)	Shaft (mm)		Hole (mm)	Shaft (mm)
(i)	80.030 80.000	80.021 80.002	(v)	450.063 450.000	450.045 450.005
(ii)	250.115 250.000	249.000 249.785	(vi)	55.046 55.000	54.970 54.940
(iii)	30.025 30.000	29.991 29.975	(vii)	100.035 100.000	99.988 99.966
(iv)	150.040 150.000	150.068 150.043	(viii)	200.046 200.000	200.079 200.060

(12 Marks)