MIT 2.008 Design and Manufacturing II

Spring 2022

Quiz 2 - Part A, In-Class Component

May 4, 2022

- Closed Book
- All work for CREDIT must be completed in this quiz document
- You are allowed one double-sided, hand written 8.5” x 11” notes sheet
- Calculators are allowed

Name: ______________________________

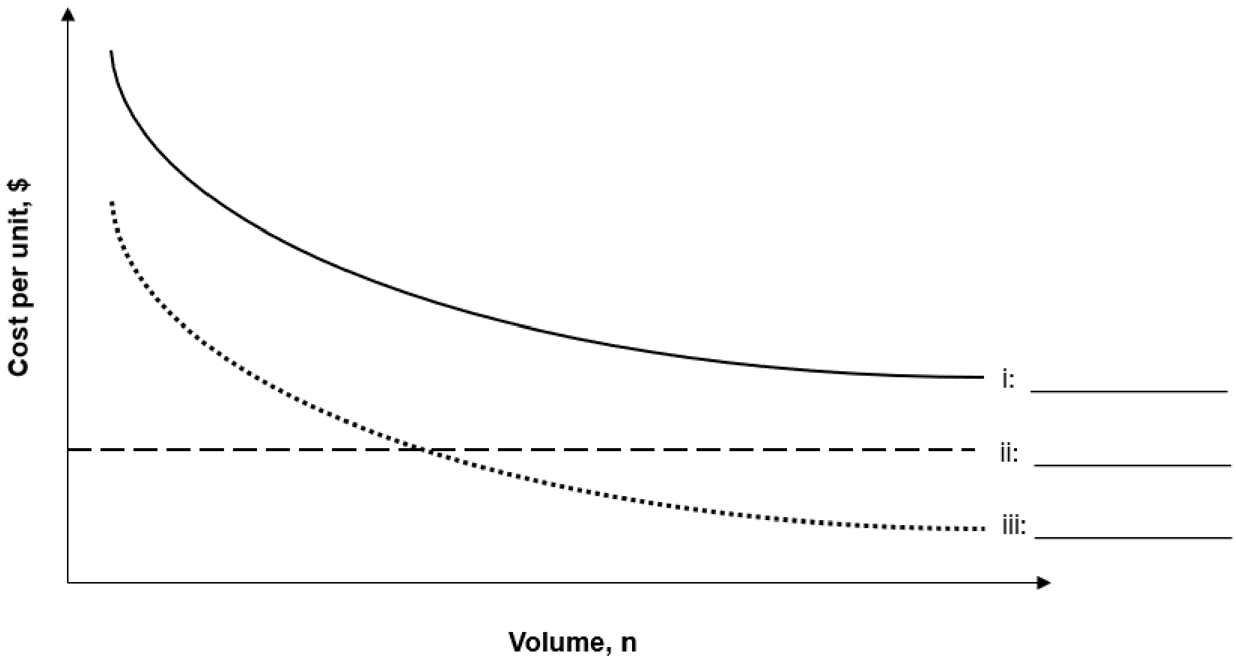
Part A, In-Class Component		
Problem 1		Out of 10 points
Problem 2		Out of 40 points
Part B, Take-Home Component		
Problem 3		Out of 50 points
Total		**100 points**

<u>Problem 1:</u> Short Answer, Multiple Choice

For each of the following questions, circle all correct answers or write in the correct answer(s).

Cost

a. A plot of cost per unit vs. volume for a typical part is shown below. The plot features 3 curves, label each curve with the correct title.



Manufacturing Systems

b. In a real manufacturing line with finite buffers, improving a machine that is not the bottleneck **[does/does not]** improve the average production rate.

c. Consider a transfer line with a bottleneck machine and non-zero buffers. Given a choice of sequencing the machines differently, do you prefer the bottleneck to be the first machine or the last machine?

i. First
ii. Last
iii. Does Not Matter

Forming

d. When evaluating the Design for Manufacturing of a forged part, it is important to consider:
    i. Parting line and flash
    ii. Draft angle
    iii. Radii of part features
    iv. Lubrication

Additive Manufacturing

e. The layer thickness in an Fused Deposition Modeling (FDM) machine is determined by the extruder-die's **[height / diameter / feed rate]**.

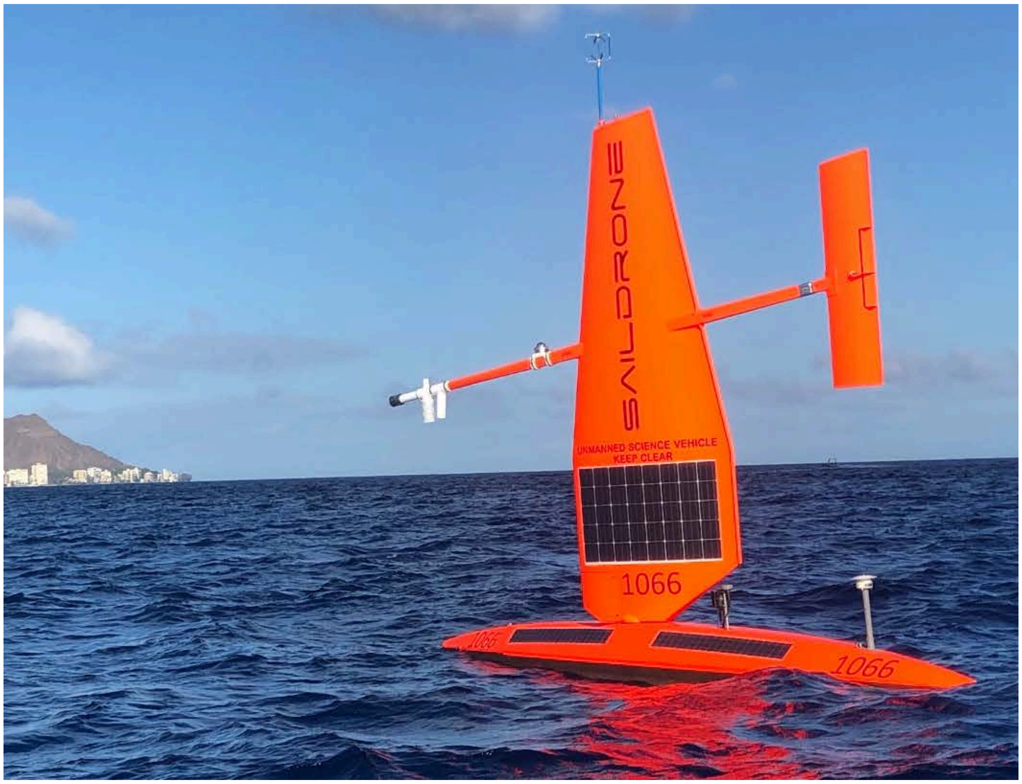
f. For Stereolithography, a **[ultraviolet / infrared / microwave]** laser beam is focused on a selected surface area of the photopolymer and then moved around in the x-y plane to **[melt / solidify]** that cross-section of the part.

Layered MFG

g. Which of the following images shows an isotropic etch?

<u>Problem 2</u>: Bending, Manufacturing Systems, and Additive Manufacturing

There is widespread interest in using distributed networks of Uncrewed Surface Vehicles (USV) to map and monitor the oceans. One manufacturer of a widely deployed USV system is Saildrone, shown in Figure 1.



Courtesy of NOAA.

Figure 1: Saildrone USV (Unmanned Surface/Science Vehicle)

You are tasked with making brackets for a mast base assembly to mount the mast to the hull of the vessel. The designs call for right angle brackets, which will be made from bending 3 mm thick sheets to an initial radius of curvature of 25 mm.

a. You are evaluating three different materials for the bracket: an aluminum alloy, a titanium alloy, and a stainless steel alloy. Rank the following materials in order of **decreasing** spring back, so the material with the most springback is 1st. You do not have to calculate spring back, but make sure to show your work (how you got to your rankings) to get full credit.

Material	Yield Stress [MPa]	Elastic Modulus [GPa]	Rank
Aluminum Alloy	293	74	
Titanium Alloy	862	105	
Stainless Steel Alloy	965	195	

b. The production line of the mast base involves bending brackets with a press and then welding the brackets to a machined mast hub. This line can be represented by a simple Transfer Line. For quality control, you barcode every bracket and scan it at every station. Your time logs show that on average a bracket spends 10 minutes in the buffer waiting for the welder.

   The Bending Station consists of one operator on a sheet metal press and they bend each bracket in approximately 1 minute.

   The Welding Station comprises 3 welders working in parallel, where each welder takes approximately 5 minutes to weld a bracket to a machined mast hub.

   You can also assume that the capacity of the buffer between the bending operation and the welding station is infinite and that there are on average 5 parts in that buffer.

   Assuming the Transfer Line is at steady state, what is the production rate that you can quote to your supervisor?

c. Your team opted to use Stainless Steel as the material for the bracket. An engineer proposes replacing the current mast base assembly, comprising 3 parts joined together, with a single stainless steel part produced via additive manufacturing.

   i. What is the name of the additive manufacturing process that the engineer proposed?

   ii. Make a sketch of the machine used to make this part, with key components of the system labeled.

   iii. Describe the physics of the process, explaining how each layer of the part is formed.

   iv. After the machine has produced the part, what additional steps must be taken before the part can be put into use?

v. Compare the material, tooling, equipment, and direct labor costs of the mast base produced with the original processes (bending + welding) vs the mast base produced with additive manufacturing. For each respective cost, state which process you expect to have a higher cost and whether that cost is **Fixed** or **Variable**.

	Bending + Welding	Additive Manufacturing
Material Cost		
Tooling Cost		
Equipment Cost		
Direct Labor Cost		

d. The Saildrone is a highly instrumented, autonomous sailing platform, utilizing solar panels to power on-board electronics. Recently there has been a widespread shortage of the computer chips necessary for some of the equipment. Chip manufacturers are expanding production as quickly as possible, but new fabs take years before they are producing chips.

   i. Define lead time and in one sentence explain the supply chain issue of requiring this new equipment.

   ii. New fabs have shifted from 8” silicon wafers to 12” silicon wafers. The larger wafer fabs employ more layers and finer feature sizes to achieve a higher memory density. In addition, the new fabs have a lower defect density. With this in mind, define the yield of a wafer and how it relates to production rate.

   iii. Wafer handling also plays a crucial role as the wafer size increases, as it becomes difficult to reduce the number of process steps due to the die density. Discuss why increasing the number of process steps can be problematic with regards to the average wait time of the wafer.

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