MIT 2.008 Design and Manufacturing II

Spring 2023

Quiz 2 - Part A, In-Class Component

May 10, 2023

- 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**

Problem 1: Short Answer Questions

Manufacturing Processes and Planning

a. Match the type of production and estimated quantity on the left with the corresponding product descriptions on the right.

Type of Production (Number Produced) — *Product*

Experimental (1-10)

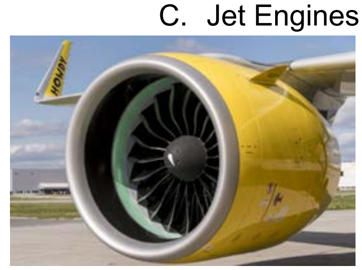
A. Red Solo Cups

Small Batch (10-5000)

B. 2.007 Robot

High Volume (5000-100000)

C. Jet Engines



Mass Production (100000+)

D. MIT Brass Rats

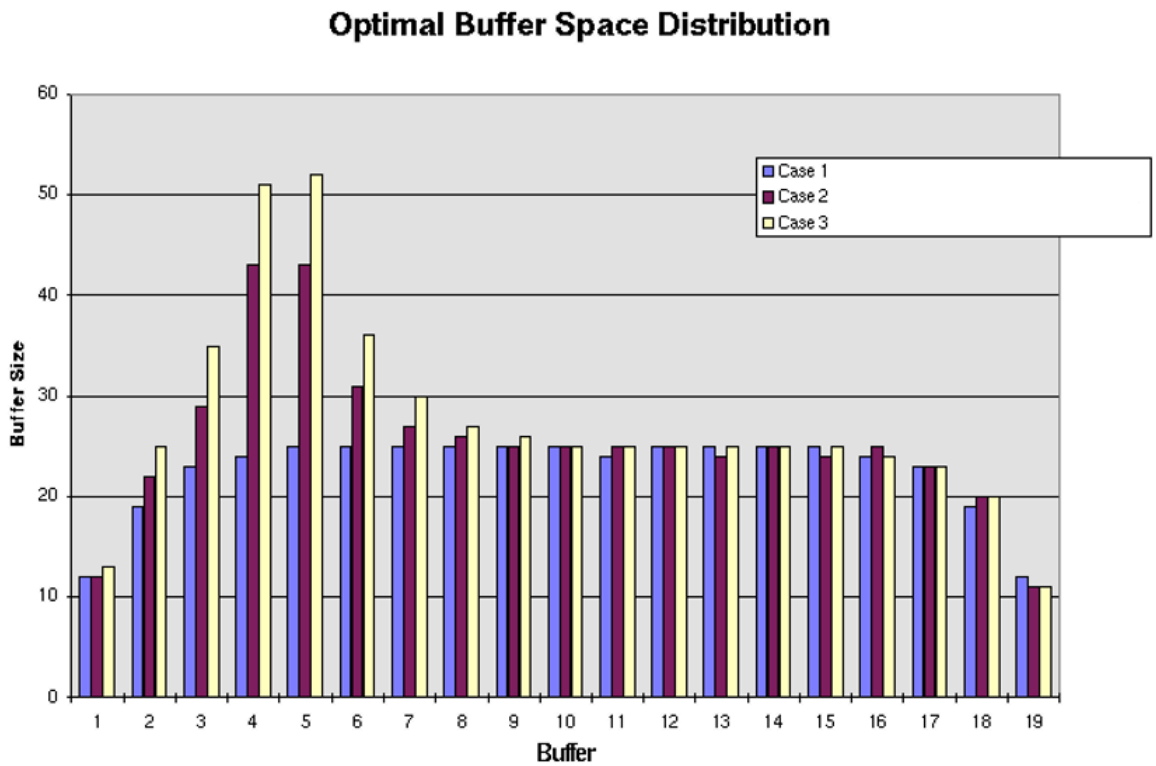
b. Which one of these products is most likely made in a **job shop**? Which product most likely can only be made **at scale with dedicated machinery and special tooling**? Briefly explain the reasoning behind your choice of product for each scenario.

Manufacturing Systems

a. In the Lean Game, you were given the option to use a *poka-yoke*, i.e. adding click guides for the toy painting activity in order to reduce defects. What are two direct impacts this technique had on your process in the game, or could have in a real-world process? What's an example of a poka-yoke technique that you have implemented or could implement in your yo-yo manufacturing and assembly?

We have been modeling 3 scenarios (Case 1, Case 2, and Case 3) for a 20-machine production line to determine the smallest allowable buffer capacity needed to meet our desired production rate. We have already determined the **optimal** buffer size for each of the 19 buffers, and the results for 3 different scenarios are shown in the image below.

In Case 1, all the machines are identical (same MTTF, same MTTR), while Case 2 and 3 contain a bottleneck. Based on the plot of buffer inventory vs buffer location, please answer questions b-c.



b. If all the machines are identical in Case 1, why do we see an “inverted bowl phenomenon” in which the required buffer capacity is smaller at the very beginning and end of the line?

c. Where is the bottleneck machine in Case 2 and Case 3 and what evidence do you have to support your conclusions?

Cost

a. You are considering a soft lithography process to prototype a microfluidics device in your lab and are interested in keeping a detailed account of expenses. How would you categorize the following costs necessary to complete the device? (Write V for variable cost, F for fixed)

   PDMS elastomer: _______

   Organic Solvents: _______

   Plasma treatment/bonding machine: _______

   Lab technician w/ hourly rate: _______

   Si wafer molds: _______

Additive Manufacturing

a. If fabricating a part with additive manufacturing, which of the following scenario(s) would **not be reasonable**. (Circle all that apply)

   Metal part with long thin overhanging features

   Custom hip implant, topology optimized for mass.

   Prototype of a new yoyo design

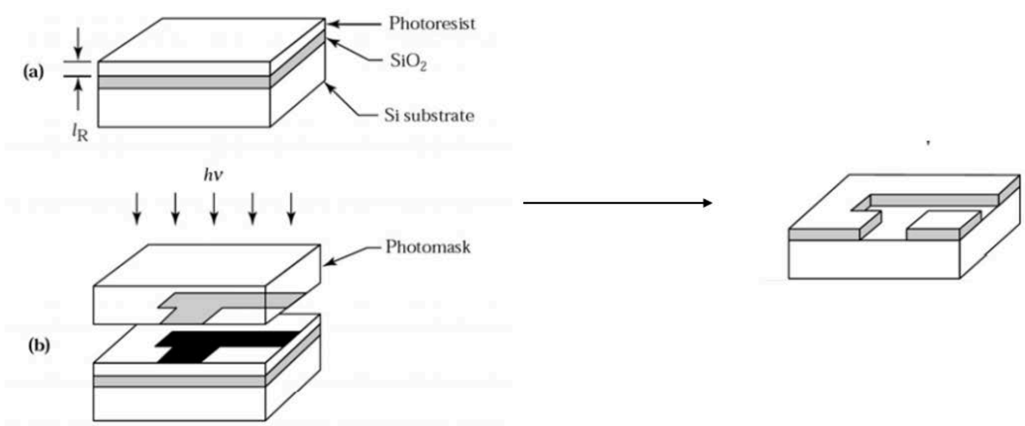
   New lids for a nationally distributed beverage

b. Which plastic additive manufacturing process is likely to give you the best surface finish and why? Fused Deposition Modeled (FDM) vs Stereolithography (SLA).

Layered Manufacturing

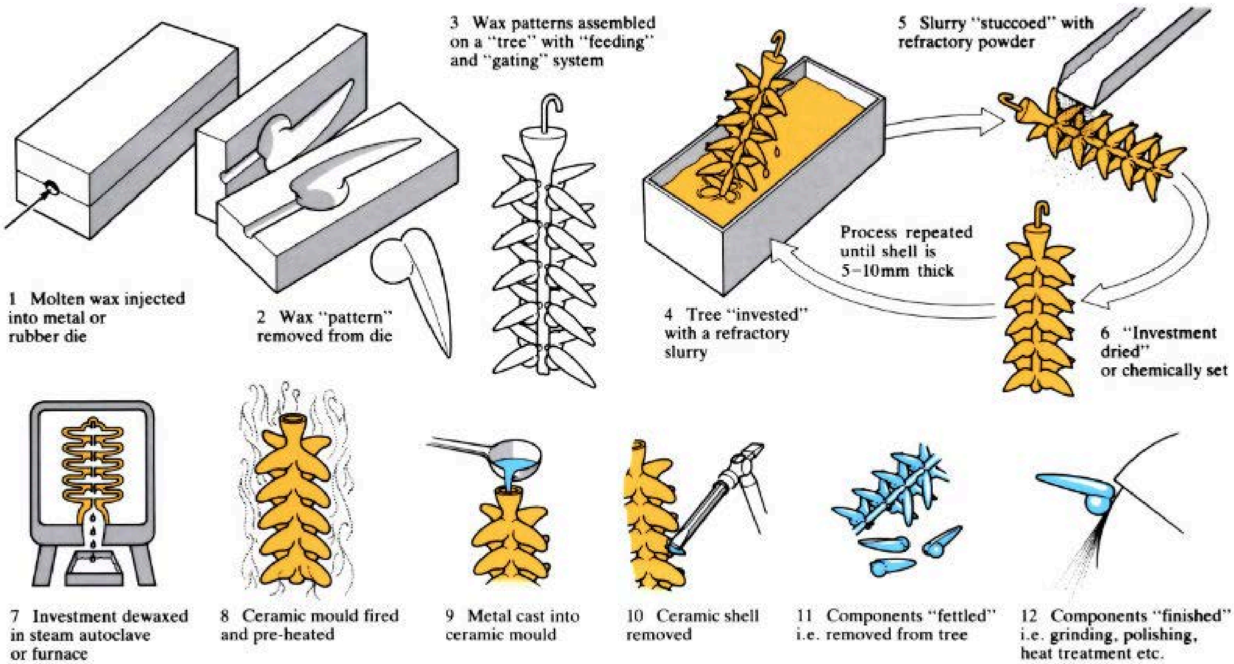
a. Name two factors that can impact the sharpness of your features during a photolithography process.

b. Circle the correct answer: Based on the mask in step b in the image below, the features produced on the substrate on the right were made with a (positive/negative) photoresist



Problem 2: Additive Manufacturing for Jewelry Production

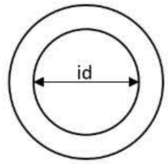
You are a part of an MIT Mech E committee reevaluating the manufacturing method for the Brass Rat. Currently these rings are made from a process called investment casting in which a wax mold is created in the shape of the ring, covered in a ceramic shell, melted away and then cast with a metal in the remaining form. This process is depicted in the image below:



There has been increased interest in how additive manufacturing could decrease the lead time between the order and manufacturing of the rings. Your job will be to evaluate the potential of an option to print the rings directly using selective laser melting (SLM) of a precious metal powder.

a) Examine the image of the Brass Rat below, are there any features on the bezel displayed that you're concerned cannot be made with this selective laser metal process? Circle or call out on the image two potentially problematic design choices and how they might be addressed?

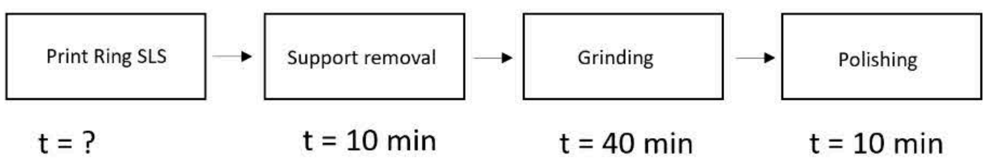
a) Given the above ring dimensions and process parameters, estimate the time in minutes to print one gold Brass Rat with the SLM process. You may approximate the ring as a hollow cylinder and should assume the infill path planning of the laser ensures no point is crossed multiple times in one layer.



Approximate dimensions
for a size 7 Brass Rat
ring height = 10 mm
ring thickness (t) = 1.5 mm
inner diameter (id) = 17 mm

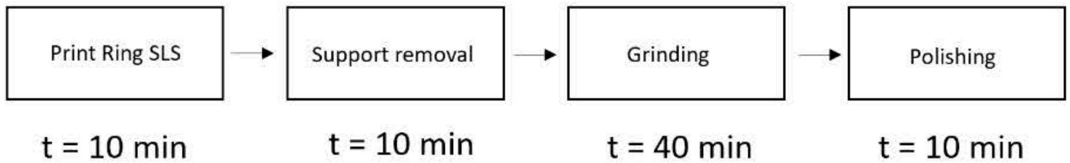
Machine Process Parameters
print layer thickness = 20 µm
laser spot size = .1 mm
linear scan speed = 20 mm/s
Interlayer speed = 5s
Build plate diameter = 80 mm

b) You’re given the following process diagram. To ensure that the printing process is not the only bottleneck, how many rings would you have to simultaneously produce? How many machines would you need to meet this demand without changing any other parameters?

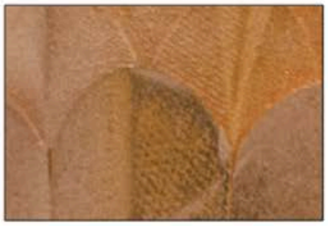


c) The initial cost for one of these machines is $100,000 USD, and the manufacturers of the SLM machine, EOS, tell you this is worth the investment given your ring target price for the new additively manufactured rings of < $2000 and an expected order size of 500 rings. Using what you have learned about manufacturing costs and the manufacturing processes, explain why this is or isn't a fair argument. Give 2 supporting reasons.

d) The committee finds a nearby manufacturing facility with non-dedicated machines that is willing to take on the task. They even managed to tune the process to reduce effective operation time for the first step to under 10 min! What is the production rate of their manufacturing line, shown below in units of parts/hr? The estimated MTTR is 30 min while the MTTF is 1200 min for each machine.



e) Another member on the team proposes a happy medium: SLA printing of the wax molds used in investment casting. Does this address any of the concerns brought up in this problem regarding rate limiting steps or feature quality? Why or why not. See the image below which compares the initial finish of a part made with investment casting of a 3D printed wax mold on the left with the initial printed part from SLM.

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