IENG 471: Facilities Planning
Midterm Exam I

Name: SOLUTION KEY Score: _____ of 135 pts = _____%

Instructions: ***Do not begin this exam until instructed to start.***

This exam is to be completed using only your Engineering Notebook and a calculator.

Note any necessary assumptions, and show your work for credit.

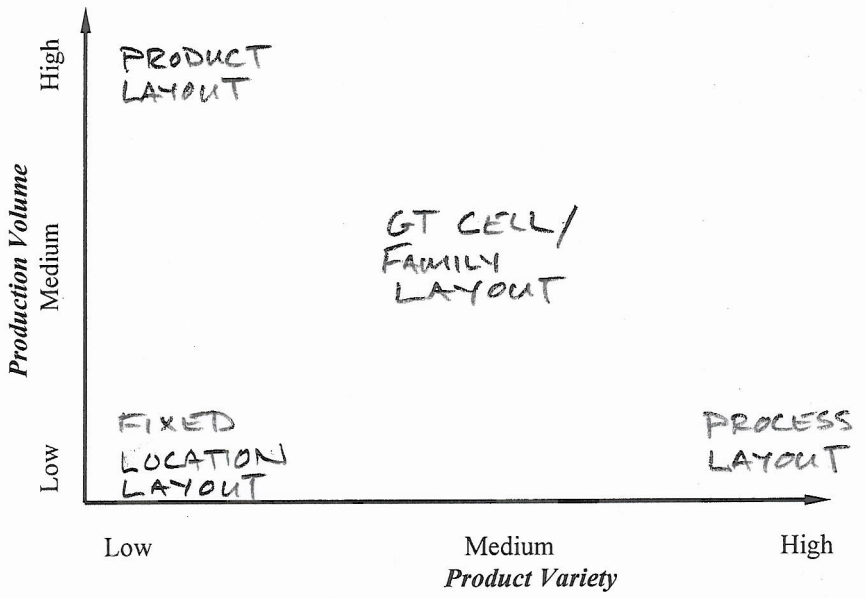
The exam is to be completed in PENCIL, five point deduction for using ink.

The exam period is 2 hours, 50 minutes in length.

1. (8 pts) Which type of the ***three production systems*** is most likely to have the following characteristics?

a.)	JOB SHOP	Process layout organization
b.)	MASS PRODUCTION	Lowest operator skill level
c.)	BATCH / GT CELL	Medium production rate
d.)	BATCH / GT CELL	A mix of general purpose & specialized production equipment
e.)	MASS PRODUCTION	Product layout organization
f.)	MASS PRODUCTION	Highest production rate
g.)	JOB SHOP	General purpose production equipment
h.)	MASS PRODUCTION	Lowest part variety

2. (8 pts) Locate each of the ***four*** *types of* ***layout patterns*** on the Volume–Variety figure below. ***(Watch axis labels!)***



3. (10 pts) Name the most appropriate chart or document to do each of the following:

a.) * OPERATIONS PROCESS CHART — Identify the various steps in making all the components of an assembly

* ROUTING IS ALSO GOOD - DISCUSSED IN IENG475

b.) PERT CHART — Estimate the makespan of a product

c.) BILL OF MATERIALS — Identify the total material costs of all components of a product

d.) * PRECEDENCE CHART — Identify which production tasks can start later and which must begin earlier

* PERT CHART IS ALSO GOOD

e.) FROM-TO CHART — Quantify the flow between departments

4. (12 pts) Give the most appropriate of the Qualitative Closeness Relationship Values to each of production situations below ***(use each letter only once, holding public safety paramount, then personal safety, production operations next most important, followed by supervisory activities; and then use reasonable judgment)***:

a.) U (LEAST IMPORTANT) — The cleaning supplies room and the CFO's office

b.) O (SUPERVISORY) — The production supervisor's office and the production floor

c.) X (DANGER... NOT CLOSE) — The flammables storage area and the arc welding station

d.) A (PUBLIC SAFETY) — The fire suppression valve and the flammables storage area

e.) I (PRODUCTION OPS) — The paint department and the paint baking oven

f.) E (PERSONAL SAFETY) — The acid etching tank and the eye-wash station

5. (8 pts) Name the measurement term ***(ends in –ility)*** that is best described in each of the following definitions:

a.) RELIABILITY — average time equipment can produce until it malfunctions

b.) AVAILABILITY — percentage of time that you can use equipment for production

c.) AVAILABILITY — a function of MTTR and MTTF

d.) MAINTAINABILITY — average time to repair and return equipment to operation

6. (27 pts, total) Use the following activity description (below) to estimate the requested values:
A production system to produce 400 000 cardboard boxes per week will be housed in a new facility. The boxes follow a sequence of (I) trim, (II) fold, and (III) hot glue, each of which is performed on a separate machine. Three shifts of 10 hours/shift are run, four days of the week, but each shift takes one half hour meal break and three personal breaks of 15 minutes, each. The following data were estimated:

	Trim (Operation 01)	*Fold (Operation 02)*	*Glue (Operation 03)*
Efficiency	95%	98%	92%
Standard Time	12 sec	18 sec	21sec
Scrap Rate	2%	1%	3%
Availability	85%	95%	90%
MTTR	1500 sec	1250 sec	1400 sec

a. (12 pts) What is the expected number of cardboard sheets that will need to be processed at ***each*** ***stage*** (trim, fold, glue) of production?

Trim: $I = \frac{400\,000 \text{ Bx/wk}}{(1-.02)(1-.01)(1-.03)} = \frac{425037.2}{\text{wk}}$ -OR- 425 038/wk

Fold: $I = \frac{400\,000 \text{ Bx/wk}}{(1-.01)(1-.03)} = \frac{416\,536.5}{\text{wk}}$ -OR- 416 537/wk

Glue: $I = \frac{400\,000 \text{ Bx/wk}}{(1-.03)} = \frac{412\,371.1}{\text{wk}}$ -OR- 412 372/wk

b. (3 pts) How many seconds of production are available each week?

$\left(\frac{3 \text{ SHIFTS}}{\text{DAY}}\right)\left(\frac{4 \text{ DAYS}}{\text{WK}}\right)\left(\frac{10 \text{ HR} - (.5 \text{ HR}) - (3)(.25 \text{ HR})}{\text{SHIFT}}\right)\left(\frac{3600 \text{ sec}}{\text{HR}}\right) = \frac{378\,000 \text{ sec}}{\text{WK}}$

c. (7 pts) What are the minimum and maximum equipment fractions, including scrap in the estimate, for the ***Fold*** machines, assuming steady-state production?

$F = \frac{SQ}{EHR} = \frac{\left(\frac{18 \text{ sec}}{\text{Bx}}\right)\left(\frac{416\,537 \text{ Bx}}{\text{wk}}\right)}{(.98)\left(\frac{378\,000 \text{ sec}}{\text{wk}}\right)(.95)} = 21.3 \text{ MACHINES (MINIMUM)}$

- OR -

22 MACHINES (MAXIMUM)

d. (5 pts) If the Fold machine takes 1250 seconds to bring it back online when it fails, find the MTTF required to have it available for production 95% of the time?

$\frac{MTTF}{MTTF + MTBF} = \text{AVAILABILITY} \Rightarrow \frac{MTTF}{MTTF + 1250 \text{ sec}} = .95$

$\Rightarrow MTTF = (.95)(MTTF + 1250 \text{ sec})$

$\Rightarrow (MTTF - .95\,MTTF) = (.95)(1250 \text{ sec})$

$\Rightarrow MTTF(1 - .95) = 1187.5 \text{ sec}$

$\Rightarrow MTTF(.05) = 1187.5 \text{ sec} \Rightarrow MTTF = \frac{1187.5 \text{ sec}}{.05} = 23750 \text{ sec}$

7. (22 pts, total) Use the following **ending** Incidence Matrix to answer the following:

a.) (6 pts) Partition the matrix (below) into GT production families:

	Part							
Machine	*A4*	*A6*	*A8*	*A3*	*A1*	*A7*	*A2*	*A5*
M4	1	1	1					
M1	1	1	1					
M3	1			1	1	1		
M5				1	1	1		
M2							1	1
M6							1	1

b.) (12 pts) List the parts and machines used for each family (above):

FAMILY 1: PARTS: A4, A6, A8 AND MACHINES: M4, M1, M3

FAMILY 2: PARTS: A3, A1, A7 AND MACHINES: M3, M5

FAMILY 3: PARTS: A2, A5 AND MACHINES: M2, M6

c.) (4 pts) State ***two*** operating implications for the part families in the above matrix:

FAMILY 3 IS COMPLETELY DISTINCT FROM FAMILIES 1 & 2
→ SO THERE ARE NO CONSTRAINTS ON HOW FAMILY 3 RUNS

FAMILIES 1 AND 2 SHARE A NEED FOR MACHINE M3, SO:
→ COULD BUY A COPY OF M3 AND OPERATE BOTH FAMILIES SEPERATELY, -OR-
→ COULD LOCATE M3 WHERE BOTH FAMILIES SHARE (CAREFUL SCHEDULING)

8. (10 pts, total) A production facility produces three primary parts (1 – 3) on three machines (A, B, C):

Foot print*	Machine A 15ft x 22ft	Machine B 8ft x 8ft	Machine C 15ft x 10ft
Product 1 Equip. Fraction	6.3	5.2	1.8
Product 2 Equip. Fraction	4.0	3.4	3.2
Product 3 Equip. Fraction	2.7	1.4	3.2

* includes operator & aisle space

If the facility is for ***GT Production*** with a ***product*** layout for a family of Products 1 & 3; and a jobshop of only Product 2, estimate the actual footprint space required for each department, and the total space for the facility.

Family 1 & 3:

6 PTS

$\lceil 6.3 + 2.7 \rceil (15')(22') + \lceil 5.2 + 1.4 \rceil (8')(8') + \lceil 1.8 + 3.2 \rceil (15')(10')$

$(9.0)(330\,FT^2) + (7.0)(64\,FT^2) + (5.0)(150\,FT^2)$

$2970\,FT^2 + 448\,FT^2 + 750\,FT^2$

Family 1,3 Space: $4168\,FT^2$

Family 2:

3 PTS

$\lceil 4.0 \rceil (15')(22') + \lceil 3.4 \rceil (8'X8') + \lceil 3.2 \rceil (15')(10')$

$(4.0)(330\,FT^2) + (4.0)(64\,FT^2) + (4.0)(150\,FT^2)$

$1320\,FT^2 + 256\,FT^2 + 600\,FT^2$

Family 2 Space: $2176\,FT^2$

1 PT

Total Space: $6344\,FT^2$

9 . (30 pts, total) Use the following activity description to estimate the requested values:
An operator spends 15 seconds loading a machine, and 15 seconds unloading a machine; during these times the machine is tied up, too. The operator then performs a sanding operation on the unloaded part for 20 seconds, using a piece of sand paper. It takes the operator 25 seconds to travel to the next (identical) machine, where she performs the sequence again. Each machine takes 60 seconds of unattended operation to form a part, and each machine costs $ 8.00/hr to operate. An operator costs $15.00/hr, and the parts are sold for $35.00/part.

a.) (5 pts) Calculate the ideal machine assignment.

$a = 15\,\text{sec} + 15\,\text{sec} = 30\,\text{sec}$ CONCURRENT TIME
$b = 20\,\text{sec} + 25\,\text{sec} = 45\,\text{sec}$ OPERATOR INDEPENDANT TIME
$t = 60\,\text{sec}$ MACHINE INDEPENDANT TIME

$$n' = \frac{a+t}{a+b} = \frac{30\,\text{sec} + 60\,\text{sec}}{30\,\text{sec} + 45\,\text{sec}} = \frac{90\,\text{sec}}{75\,\text{sec}} = 1.2 \text{ MACHINES/OPERATOR}$$

b.) (7 pts) What is the Total Cost per unit if the ideal machine assignment is used SINCE $m \leq n'$

$$TC(m) = \frac{(C_o + mC_m)(a+t)}{m}$$

$$TC(m) = \frac{\left[\left(\$15/\text{HR}\right) + 1.2\left(\$8/\text{HR}\right)\right]\left(\frac{1\,\text{HR}}{3600\,\text{SEC}}\right)(30\,\text{sec} + 60\,\text{sec})}{1.2}$$

$$= \$0.5125/\text{PART}$$

c.) (5 pts) Estimate the steady-state cycle time if ***two machines are assigned to the operator*** SINCE $m > n'$

$$T_c = m(a+b)$$
$$= 2(30\,\text{sec} + 45\,\text{sec})$$
$$= 150\,\text{SEC} \quad \text{-OR-} \quad 2.5 \text{ MINUTES}$$

d.) (7 pts) What is the Total Cost per unit if ***two machines are assigned to the operator?*** SINCE $m > n'$

$$TC(m) = (C_o + mC_m)(a+b)$$
$$= \left[\left(\$15/\text{HR}\right) + 2\left(\$8/\text{HR}\right)\right]\left(\frac{1\,\text{HR}}{3600\,\text{SEC}}\right)(30\,\text{sec} + 45\,\text{sec})$$
$$= \$0.64583\overline{3}/\text{PART}$$

e.) (6 pts) ***If two machines are assigned to the operator***, (i) what is the total idle time during a steady state cycle, and (ii) what asset (operator or machine) is fully utilized? SINCE $m > n'$, MACHINE IS IDLE

4 PTS i) $I_m = T_c - (a+t)$
$= 150\,\text{SEC} - (30\,\text{sec} + 60\,\text{sec})$
$= 60\,\text{SEC}$

2 PTS ii) SINCE THE MACHINE IS IDLE, THE OPERATOR IS FULLY UTILIZED