56:171
Operations Research
Fall 1998

Quizzes

Dept of Mechanical & Industrial Engineering
University of Iowa

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<><><><><><><><><><> Quiz #1 - September 9, 1998 <><><><><><><><><>

For each statement, indicate "+"=**true** or "o"=**false**.

Part I: LINDO

___ a. After the LP model has been entered, the **SOLVE** command finds the optimal solution.

___ b. In the simplex method (as described in the lectures, not the textbook), the quantity -Z serves as a basic variable, where Z is the value of the objective function.

___ c. To begin your entry of the LP model into LINDO, you should use the command "**ENTER**".

___ d. In a basic LP solution, the nonbasic variables equal zero.

___ e. If a slack variable S_i for row i is basic in the optimal solution, then variable X_i cannot be basic.

___ f. The "minimum ratio test" is used to select the pivot column in the simplex method for linear programming.

___ g. LINDO does not accept "strict inequalities" such as X + 2Y < 10, so that you must enter X + 2Y <= 10 instead.

___ h. When entering your LP model, the last constraint which you enter should be followed by "**END**".

___ i. The **PRINT** command may be used to print any LINDO output which has previously appeared on the monitor.

___ j. LINDO assumes that all variables are restricted to be nonnegative, so that you need not explicitly enter these constraints.

___ k. After you have entered the objective function, you must enter "**SUBJECT TO**" before entering the first constraint.

___ l. When you enter an LP formulation into LINDO, you must first convert all inequalities to equations.

___ m. When you enter an LP formulation into LINDO, you must manipulate your constraints so that all variables appear on the left, and all constants on the right.

Multiple-Choice:

___n. If you make a mistake in choosing the pivot column in the simplex method, the solution in the next tableau

(a) will be nonbasic
(b) will be infeasible
(c) will have a worse objective value
(d) *None of the above*

___o. If you make a mistake in choosing the pivot row in the simplex method, the solution in the next tableau

(a) will be nonbasic
(b) will be infeasible
(c) will have a worse objective value
(d) *None of the above*

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Part II: Investment problem

Consider the following investment problem: You now have $100 available for investment (beginning of year #1). Your objective is to maximize the value of this initial investment after four years, i.e., the end of year #4 or equivalently, the beginning of year #5. The available investments are:

- Investment **A** is available only at the beginning of years 1 and 2; each $1 invested in A will be returned in two equal payments of $0.70 at the beginning of each of the following 2 years. (For example, if you invest $1 now, at the beginning of year 1, then you receive $0.70 at the beginning of year 2 and another $0.70 at the beginning of year 3.)
- Investment **B** is available only once, at the beginning of year 2; each $1 invested in B at the beginning of year 2 returns $2 after 3 years, i.e., the beginning of year 5.
- A Money Market fund (**R**) is available every year; each $1 invested in this way will return $1.10 after 1 year.

The following table displays these cash flows. For example, -1 indicates $1 put into the investment, and +0.70 indicates $0.70 received from the investment.

begin year #	A1	A2	B	R1	R2	R3	R4
1	-1			-1			
2	+0.7	-1	-1	+1.1	-1		
3	+0.7	+0.7			+1.1	-1	
4		+0.7				+1.1	-1
5			+2				+1.1

p. Complete the equation: 0.7A2 + 1.1R3 - R4 = ___________

q. The objective should be to maximize *(select one):*

___ 1.4A2 + 2B + 1.1R4
___ 2B + 1.1R4
___ 1.4A1 + 1.4A2 + 2B + 1.1R1 + 1.1R2 + 1.1R3 + 1.1R4
___ 0.4A2 + 1B + 0.1R4
___ none of the above

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<><><><><><><> Quiz #2 - September 16, 1998 <><><><><><><>

Consider the simplex tableaus below, where the objective is to maximized or minimized, as specified. In each tableau, circle every element which could be selected for the next pivot such that (unless there is degeneracy) the objective function is improved and the solution remains feasible.

	-Z	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	RHS
MIN	1	3	0	-1	0	2	-2	0	0	1	-16
	0	0	0	2	0	-1	3	1	0	-2	8
	0	2	1	3	0	0	-1	0	0	3	0
	0	-1	0	0	1	1	1	0	0	1	6
	0	1	0	-4	0	2	0	0	1	0	5

	-Z	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	RHS
MAX	1	-2	0	3	0	-2	4	0	0	2	-24
	0	0	0	2	0	-1	3	1	0	-2	4
	0	2	1	3	0	0	1	0	0	3	8
	0	-1	0	0	1	1	-1	0	0	1	2
	0	1	0	-4	0	2	0	0	1	0	1

For each situation (1) through (6) below, enter both a variable and a value (or a range of values, e.g., "≥0") which would result in that situation.

	-z	X_1	X_2	X_3	X_4	X_5	X_6	RHS
(MIN)	1	0	-1	**a**	-2	0	**b**	-11
	0	0	**c**	0	3	1	-2	6
	0	0	-1	1	-1	0	3	**d**
	0	1	-3	0	**e**	0	5	15

	Variable	Value (or range of values)
1. Optimal basic solution is unbounded	________	________
2. Current basic solution is degenerate	________	________
3. A tableau represents a basic solution	________	________
4. X_4 will enter the basis and X_5 remains in the basis	________	________
5. If the objective were to be MAXimized instead, the current basic solution is optimal	________	________
6. The current basic solution is infeasible	________	________

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<><><><><><><> Quiz #3 - September 23, 1998 <><><><><><><>

The following questions refer to the LP model for PAR, Inc. and its LINDO output. Select the answers from the list at the bottom of the quiz and **write only the alphabetic letter** in the blank.

✠✠✠✠ PAR, inc. ✠✠✠✠

Processing times (hrs/golf bag):

	Cut & Dye	Sew	Finish	Inspect & Pack
Standard	0.7	0.5	1	0.1
Deluxe	1	0.8666	0.6666	0.25
Available hrs	630	600	708	135

Variables:

X1 = production of STANDARD golf bags (bags/quarter)
X2 = production of DELUXE golf bags (bags/quarter)

LINDO output:

```
 MAX     10 X1 + 9 X2
 SUBJECT TO
        2)   0.7 X1 + X2 <=   630
        3)   0.5 X1 + 0.86666 X2 <=   600
        4)   X1 + 0.66666 X2 <=   708
        5)   0.1 X1 + 0.25 X2 <=   135
 END

        OBJECTIVE FUNCTION VALUE
        1)    7668.01200

  VARIABLE        VALUE          REDUCED COST
        X1       540.003110           .000000
        X2       251.997800           .000000

       ROW   SLACK OR SURPLUS     DUAL PRICES
        2)          .000000          4.375086
        3)       111.602000           .000000
        4)          .000000          6.937440
        5)        18.000232           .000000

RANGES IN WHICH THE BASIS IS UNCHANGED:

                           OBJ COEFFICIENT RANGES
 VARIABLE         CURRENT        ALLOWABLE        ALLOWABLE
                    COEF          INCREASE         DECREASE
       X1       10.000000         3.500135         3.700000
       X2        9.000000         5.285715         2.333400

                           RIGHTHAND SIDE RANGES
      ROW         CURRENT        ALLOWABLE        ALLOWABLE
                    RHS           INCREASE         DECREASE
        2      630.000000        52.364582       134.400000
        3      600.000000         INFINITY       111.602000
        4      708.000000       192.000010       128.002800
        5      135.000000         INFINITY        18.000232
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THE TABLEAU

ROW (BASIS)	X1	X2	SLK 2	SLK 3	SLK 4	SLK5	
1 ART	.000	.000	4.375	.000	6.937	.000	7668.012
2 X2	.000	1.000	1.875	.000	-1.312	.000	251.998
3 SLK 3	.000	.000	-1.000	1.000	.200	.000	111.602
4 X1	1.000	.000	-1.250	.000	1.875	.000	540.003
5 SLK 5	.000	.000	-.344	.000	.141	1.000	18.000

1. There are _____ unused hours in the finishing department.

2. The reduced cost of the variable X2 is ______ .

3. If the profit per STANDARD bag were to increase from $10 to $12, the quantity of these bags which should then be manufactured would
   |__| increase |__| decrease |__| remain the same |__| not sufficient info.
4. If the profit per DELUXE bag were to increase from $9 to $15, the quantity of these bags which should then be manufactured would
   |__| increase |__| decrease |__| remain the same |__| not sufficient info.
5. a.) If an additional hour were available in the Cutting&Dyeing Dept., PAR would be able to obtain an additional $________ in profits. *If positive, answer parts (b) & (c):*
   b.) To determine the effect of this change, we would consider the slack variable for row# __ to change from ____ to ______.
   c.) According to the substitution rates,
   the change in the number of STANDARD bags is ____ (circle: increase or decrease?).
   the change in the number of DELUXE bags is ____ (circle: increase or decrease?).

6. a.) If an additional hour were available in the Sewing Dept., PAR would be able to obtain an additional $________ in profits. *If positive, answer parts (b) & (c):*
   b.) To determine the effect of this change, we would consider the slack variable for row# __ to change from ____ to ______.
   c.) According to the substitution rates,
   the change in the number of STANDARD bags is ____ (circle: increase or decrease?).
   the change in the number of DELUXE bags is ____ (circle: increase or decrease?).

For each statement, indicate "+"=**true** or "o"=**false**.

_____ 6. If the primal LP has an equality constraint, the corresponding dual variable must be zero.
_____ 7. If an LP problem has 3 constraints (not including non-negativity) and 5 variables, then its dual problem also has 3 constraints (not including non-negativity) and 5 variables.
_____ 8. If the increase in the right-hand-side of a "tight" constraint remains less than the "ALLOWABLE INCREASE" reported by LINDO, then the optimal values of all variables will be unchanged.
_____ 9. If you increase the right-hand-side of a "≤" constraint in a minimization LP, the optimal objective value will either increase or stay the same.
_____ 10. The optimal basic solution to an LP with 4 constraints (excluding non-negativity constraints) can have at most 4 positive decision variables.
_____ 11. In the "symmetric primal/dual pair", one LP problem is a MINIMIZE problem with " " constraints.
_____ 12. If the increase in the cost of a nonbasic variable remains less than the "ALLOWABLE INCREASE" reported by LINDO, then the optimal values of all variables will be unchanged.
_____ 13. At the completion of the revised simplex method applied to an LP, the simplex multipliers give the optimal solution to the dual of the LP.
_____ 14. In the "symmetric primal/dual pair", one LP problem is a MAXIMIZE problem with " " constraints.
_____ 15. If a minimization LP problem has a cost which is unbounded below, then its dual problem has an objective (to be maximized) which is unbounded above.
_____ 16. The "reduced cost" in LP provides an estimate of the change in the objective value when the cost of a primal variable changes.

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<><><><><><><><><><> Quiz #6 - November 2, 1998 <><><><><><><><><><>

Integer Programming Model Formulation. Coach Night is trying to choose the starting linerup for the basketball team. The team consists of seven players who have been rated (on a scale of 1=poor to 3=excellent) according to their ball-handling, shooting, rebounding, and defensive abilities. The positions that each player is allowed to play (G=guard, C=center, F=forward) and the player's abilities are:

Player	Position	Ball-handling	Shooting	Rebounding	Defense
1	G	3	3	1	3
2	C	2	1	3	2
3	G-F	2	3	2	2
4	F-C	1	3	3	1
5	G-F	1	3	1	2
6	F-C	3	1	2	3
7	G-F	3	2	2	1

For each stated constraint, indicate the mathematical expression of that constraint from the list below. *(Note: if more than one answer is correct, only one answer is required.)*

___ 1. The starting lineup is to consist of five players.
___ 2. At least 2 members must be able to play guard.
___ 3. If player 7 starts, then player 3 cannot start.
___ 4. If player 2 starts, then player 6 must start.
___ 5. Either player 3 or player 5 (or both) must start.
___ 6. The average rebounding rating of the starting lineup must be at least 2.
___ 7. At least one member must be able to play center.
___ 8. At least 2 members must have a rating of 3 in shooting.
___ 9. Not more than one of the members may have a rebounding rating of 1.
___ 10. At least four members must be able to play at more than one position.

a. $X_1 + X_2 \leq 1$

b. $X_1 + X_3 + X_5 + X_7 \leq 2$

c. $X_5 \geq X_1$

d. $X_3 + X_7 \leq 1$

e. $X_1 + 3X_2 + 2X_3 + 3X_4 + X_5 + 2X_6 + 2X_7 \geq 10$

f. $X_1 + X_5 \leq 1$

g. $X_3 + X_4 + X_5 + X_6 + X_7 \geq 4$

h. $X_1 + X_3 + X_4 + X_5 \geq 2$

i. $X_2 \geq X_6$

j. $X_3 + X_7 \geq 1$

k. $X_1 + X_2 \geq 1$

l. $X_1 + 3X_2 + 2X_3 + 3X_4 + X_5 + 2X_6 + 2X_7 \geq 2$

m. $X_1 \geq X_2$

n. $X_2 + X_4 + X_6 \geq 1$

o. $X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 = 5$

p. $X_3 + X_5 \geq 1$

q. $X_3 \geq X_7$

r. $X_3 \leq X_7$

s. $X_2 \leq X_6$

t. $X_1 + X_3 + X_5 + X_7 \geq 2$

u. $X_2 + X_6 \leq 1$

v. $X_1 + X_3 + X_4 + X_5 \leq 2$

w. $X_6 \geq X_2$

x. $X_5 \leq X_1$

y. $X_1 + X_3 + X_4 + X_5 \geq 2$

z. $X_3 + X_5 \geq 1$

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<><><><><><><><><><> Quiz #7 - November 11, 1998 <><><><><><><><><><>

Careful study of a reservoir over the past 20 years has shown that, if the reservoir was full at the beginning of the summer, then the probability it would be full at the beginning of the following summer is **60%**, independent of its status in previous years. On the other hand, if the reservoir was not full at the beginning of one summer, the probability it would be full at the beginning of the following summer is only **20%**. Define a Markov chain model of this reservoir, with the states (1)"full" and (2)"not full". The transition probability matrix and several higher powers, as well as some other computations, are shown below.

____ 1. If the reservoir was full at the beginning of summer 1997, what is the probability that it will be full at the beginning of summer 1999 (rounded to the nearest 10%)?
a. 20% b. 30% c. 40%
d. 50% e. 60% f. none of the above

____ 2. Suppose the reservoir was full at the beginning of summer 1997, and consider the first year that follows in which the reservoir is not full at the beginning of the summer. What is the probability that this occurs in 1999? (rounded to the nearest 10%)
a. 10% b. 20% c. 30%
d. 40% e. 50% f. none of the above

____ 3. If the reservoir was full at the beginning of summer 1997, the expected number of years until it will next be "not full" is: (choose nearest value)
a. 2 b. 2.5 c. 3
d. 3.5 e. 5 f. none of the above

____ 4. If the reservoir was full at the beginning of summer 1997, the probability that 2000 is the first year it is not full is (rounded to the nearest 10%)
a. 20% b. 30% c. 40%
d. 50% e. 60% f. none of the above

____ 5. If the reservoir was full at the beginning of summer 1997, the probability that in 2000 it is not full is (rounded to the nearest 10%)
a. 20% b. 30% c. 40%
d. 50% e. 60% f. none of the above

____ 6. During the next hundred years, in how many the reservoir be full at the beginning of the summer, as predicted by this model? (choose nearest value)
a. 20 b. 33 c. 40
d. 60 e. 67 f. none of the above

____ 7. If the reservoir is full at the beginning of **both** summer 1997 and summer 1998, the probability that it will be full at the beginning of summer 1999 is (rounded to the nearest 10%)
a. 40% b. 50% c. 60%
d. 70% e. 80% f. none of the above

____ 8. If the reservoir was full at the beginning of summer 1997, what is the expected number of years until it is expected to be full again? (choose nearest value)
a. 1.5 b. 2 c. 2.5
d. 3 e. 5 f. none of the above

____ 9. If the reservoir was full at the beginning of summer 1997, the probability that 2000 is the first year it is full again is (rounded to the nearest 10%)
a. 10% b. 20% c. 30%
d. 40% e. 50% f. none of the above

____ 10. Consider a different reservoir: if it was full at the beginning of the summer, then the probability it would be full at the beginning of the following summer is **50%**, while if the reservoir was not full at the beginning of one summer, the probability it would be full at the beginning of the following summer is **25%**. The steadystate probability distribution π for this Markov chain must satisfy the following equation:
a. $\pi_1 + \pi_2 = 0$ b. $\pi_2 = 0.25\pi_1 + 0.75\pi_2$ c. $\pi_2 = 0.75\pi_1 + 0.25\pi_2$
d. $\pi_2 = 0.5\pi_1 + 0.25\pi_2$ e. $0.5\pi_1 + 0.5\pi_2 = 1$ f. none of the above

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You may use the computational results below to answer questions (1) through (9):

$$P = \begin{bmatrix} 0.6 & 0.4 \\ 0.2 & 0.8 \end{bmatrix}$$

$$P^2 = \begin{bmatrix} 0.44 & 0.56 \\ 0.28 & 0.72 \end{bmatrix}$$

$$P^3 = \begin{bmatrix} 0.376 & 0.624 \\ 0.312 & 0.688 \end{bmatrix}$$

$$P^4 = \begin{bmatrix} 0.3504 & 0.6496 \\ 0.3248 & 0.6752 \end{bmatrix}$$

First Visit Probabilities

$$F = \begin{bmatrix} 0.6 & 0.4 \\ 0.2 & 0.8 \end{bmatrix}$$

$$F^{(2)} = \begin{bmatrix} 0.08 & 0.24 \\ 0.16 & 0.08 \end{bmatrix}$$

$$F^{(3)} = \begin{bmatrix} 0.064 & 0.144 \\ 0.128 & 0.048 \end{bmatrix}$$

$$F^{(4)} = \begin{bmatrix} 0.0512 & 0.0864 \\ 0.1024 & 0.0288 \end{bmatrix}$$

i	π_i
1	0.33333333
2	0.66666667

$$M = \begin{bmatrix} 3 & 2.5 \\ 5 & 1.5 \end{bmatrix}$$

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<><><><><><><><><><> Quiz #8 - November 18, 1998 <><><><><><><><><><>

Part I: At the end of each day, a store observes its stock-on-hand (SOH). If the SOH is 2 or fewer, enough is ordered to bring the on-hand inventory level up to 4. During each day, demand is 1, 2, or 3 units with probability $^1/4$, $^1/2$, and $^1/4$, respectively. A Markov chain model is defined, with state 1 = {SOH=0}, state 2 = {SOH=1}, ... state 5 = {SOH=4}.

____ 1. If the SOH is 3 units at the end of the day on Monday, what is the probability that there is a stockout (SOH=0) at the end of the day Wednesday? *(Select nearest value.)*

a. 5% b. 10% c. 15%
d. 20% e. 25% f. 30%

____ 2. The steadystate probability distribution π for this Markov chain must satisfy the following equation:

a. $p_1 = 0.25\, p_3 + 0.5\, p_4 + 0.25\, p_5$ b. $0.25\, p_3 + 0.5\, p_4 + 0.25\, p_5 = 0$
c. $0.25\, p_1 + 0.25\, p_2 + 0.25\, p_3 + 0.25\, p_4 + 0.5\, p_5 = 0$
d. $0.25\, p_1 + 0.25\, p_2 + 0.25\, p_3 + 0.25\, p_4 + 0.5\, p_5 = p_3$
e. $0.25\, p_3 + 0.5\, p_4 + 0.25\, p_5 = p_3$ f. *none of the above*

___ 3. If the SOH=4 Monday p.m., the expected number of days until the next stock-out occurs is *(Select nearest value.)*

a. 2.5 days b. 5 days c. 7.5 days
d. 10 days e. 12.5 days f. 15 days

___ 4. If the SOH=0 Monday p.m., the probability that the next stockout to occur is observed Wednesday p.m. is (rounded to the nearest 1%):

a. 5% b. 10% c. 15%
d. 20% e. 25% f. 30%

___ 5. If the SOH=4 Monday p.m., the expected number of stockouts during the remainder of the week, i.e., during the next four days, is *(Select nearest value.)*

a. 0.2 b. 0.4 c. 0.6
d. 0.8 e. 1 f. >1.2

$$P = \begin{bmatrix} 0 & 0 & 0.25 & 0.5 & 0.25 \\ 0 & 0 & 0.25 & 0.5 & 0.25 \\ 0 & 0 & 0.25 & 0.5 & 0.25 \\ 0.25 & 0.5 & 0.25 & 0 & 0 \\ 0 & 0.25 & 0.5 & 0.25 & 0 \end{bmatrix} \qquad F = \begin{bmatrix} 0 & 0 & 0.25 & 0.5 & 0.25 \\ 0 & 0 & 0.25 & 0.5 & 0.25 \\ 0 & 0 & 0.25 & 0.5 & 0.25 \\ 0.25 & 0.5 & 0.25 & 0 & 0 \\ 0 & 0.25 & 0.5 & 0.25 & 0 \end{bmatrix}$$

$$P^2 = \begin{bmatrix} 0.125 & 0.3125 & 0.3125 & 0.1875 & 0.0625 \\ 0.125 & 0.3125 & 0.3125 & 0.1875 & 0.0625 \\ 0.125 & 0.3125 & 0.3125 & 0.1875 & 0.0625 \\ 0 & 0 & 0.25 & 0.5 & 0.25 \\ 0.0625 & 0.125 & 0.25 & 0.375 & 0.1875 \end{bmatrix} \qquad F^2 = \begin{bmatrix} 0.125 & 0.3125 & 0.25 & 0.1875 & 0.0625 \\ 0.125 & 0.3125 & 0.25 & 0.1875 & 0.0625 \\ 0.125 & 0.3125 & 0.25 & 0.1875 & 0.0625 \\ 0 & 0 & 0.1875 & 0.5 & 0.25 \\ 0.0625 & 0.125 & 0.125 & 0.375 & 0.1875 \end{bmatrix}$$

$$M = \begin{bmatrix} 12.889 & 5.2727 & 3.5152 & 2.2222 & 6 \\ 12.889 & 5.2727 & 3.5152 & 2.2222 & 6 \\ 12.889 & 5.2727 & 3.5152 & 2.2222 & 6 \\ 10.667 & 3.6364 & 3.6364 & 3.2222 & 7 \\ 13.333 & 4.5455 & 2.7879 & 2.6667 & 7.25 \end{bmatrix} \qquad \sum_{n=1}^{4} P^n = \begin{bmatrix} 0.26953 & 0.66406 & 1.125 & 1.3359 & 0.60547 \\ 0.26953 & 0.66406 & 1.125 & 1.3359 & 0.60547 \\ 0.26953 & 0.66406 & 1.125 & 1.3359 & 0.60547 \\ 0.42188 & 0.92188 & 1.0781 & 1.0781 & 0.5 \\ 0.22266 & 0.76953 & 1.3242 & 1.2305 & 0.45313 \end{bmatrix}$$

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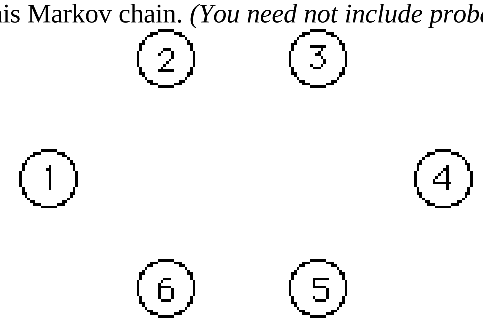
Part II: The college admissions officer has modeled the path of a student through the Engineering College as a Markov chain. Each student's classification is observed at the beginning of each fall semester, and a transition probability matrix was computed, based upon past history. For example, if a student is a junior at the beginning of the current fall semester, there is an 80% chance that he will be a senior at the beginning of the next fall semester, a 15% chance that he will still be a junior, and a 5% chance that he will have quit. (Assume that once a student quits, he never re-enrolls.)

State	Description	State	Description
1	Freshman	4	Senior
2	Sophomore	5	Drop-out
3	Junior	6	Graduated

6. Indicate the possible transitions in the diagram for this Markov chain. *(You need not include probabilities!)*



7. Which states are transient? *(circle:)* 1 2 3 4 5 6

8. Which states are recurrent? *(circle:)* 1 2 3 4 5 6

9. Which states are absorbing? *(circle:)* 1 2 3 4 5 6

___ 10. What is the probability that, at the beginning of his/her fourth year in the college, an entering freshman is classified as a senior? *(Choose nearest answer)*

a. 10%	b. 30%	c. 50%	d. 70%	e. 90%
f. 20%	b. 40%	h. 60%	i. 80%	j. >95%

___ 11. If a student transfers into the college as a junior, how many years can he or she expect to spend as a student in the college? *(Choose nearest answer)*

a. 0.25	b. 0.75	c. 1.25	d. 1.75	e. 2.25
f. 0.5	g. 1.0	h. 1.5	i. 2.0	j. >2.5

___ 12. If a student has survived to the point that he or she has been classified as a junior, what is the probability that he or she eventually graduates? *(Choose nearest answer)*

a. 10%	b. 30%	c. 50%	d. 70%	e. 90%
f. 20%	g. 40%	h. 60%	i. 80%	j. >95%

___ 13. What is the probability that an entering freshman eventually will graduate? *(Choose nearest answer)*

a. 50%	b. 60%	c. 70%	d. 80%	e. 90%
f. 55%	g. 65%	h. 75%	i. 85%	j. >95%

Name ________________________________

Transition probabilities (P)

from \ to	1	2	3	4	5	6
1	0.1	0.8	0	0	0.1	0
2	0	0.1	0.85	0	0.05	0
3	0	0	0.15	0.8	0.05	0
4	0	0	0	0.1	0.05	0.85
5	0	0	0	0	1	0
6	0	0	0	0	0	1

E = Expected No. Visits to Transient States

from \ to	1	2	3	4
1	1.11111	0.98765	0.98765	0.87791
2	0	1.11111	1.11111	0.98765
3	0	0	1.17647	1.04575
4	0	0	0	1.11111

P^2

from \ to	1	2	3	4	5	6
1	0.01	0.16	0.68	0	0.15	0
2	0	0.01	0.2125	0.68	0.0975	0
3	0	0	0.0225	0.2	0.0975	0.68
4	0	0	0	0.01	0.055	0.935
5	0	0	0	0	1	0
6	0	0	0	0	0	1

P^3

from \ to	1	2	3	4	5	6
1	0.001	0.024	0.238	0.544	0.193	0
2	0	0.001	0.040375	0.238	0.142625	0.578
3	0	0	0.003375	0.038	0.108625	0.85
4	0	0	0	0.001	0.0555	0.9435
5	0	0	0	0	1	0
6	0	0	0	0	0	1

A = Absorption Probabilities

from \ to	5	6
1	0.253772	0.746227
2	0.160493	0.839506
3	0.111111	0.888888
4	0.055555	0.944444

P^4

from \ to	1	2	3	4	5	6
1	0.0001	0.0032	0.0561	0.2448	0.2334	0.4624
2	0	0.0001	0.00690625	0.0561	0.15659375	0.7803
3	0	0	0.00050625	0.0065	0.11069375	0.8823
4	0	0	0	0.0001	0.05555	0.94435
5	0	0	0	0	1	0
6	0	0	0	0	0	1

Name ________________________________

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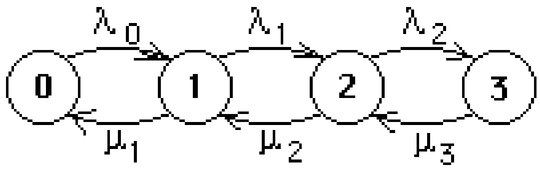
A machine operator has sole responsibility for keeping three semi-automatic machines busy. The time required to ready a machine (unloading & reloading) has exponential distribution with mean 15 minutes. The machine will then run unattended for an average of 1 hour (but with actual time having exponential distribution) before it requires the operator's attention again.



_____ 1. The Markov chain model diagrammed above is *(select one or more):*

- a. a discrete-time Markov chain
- b. a continuous-time Markov chain
- c. a Birth-Death process
- d. an M/M/1 queue
- e. an M/M/3 queue
- f. an M/M/1/3 queue
- g. an M/M/1/3/3 queue
- h. a Poisson process

___ 2. The value of λ_2 is

- a. 1/hr.
- b. 2/hr.
- c. 3/hr.
- d. 4/hr.
- e. 0.5/hr.
- f. *none of the above*

___ 3. The value of μ_2 is

- a. 1/hr.
- b. 2/hr.
- c. 3/hr.
- d. 0.5/hr.
- e. 0.5/hr.
- f. *none of the above*

___ 4. The value of λ_0 is

- a. 1/hr.
- b. 2/hr.
- c. 3/hr.
- d. 0.5/hr.
- e. 0.5/hr.
- f. *none of the above*

___ 5. The steady-state probability π_0 is computed by solving

- a. $\frac{1}{\pi_0} = 1 + \frac{3}{4} + \left(\frac{3}{4}\right)^2 + \left(\frac{3}{4}\right)^3 \approx \frac{1}{0.366}$
- b. $\frac{1}{\pi_0} = 1 + \frac{3}{4} + \frac{1}{2}\times\frac{3}{4} + \frac{1}{4}\times\frac{1}{2}\times\frac{3}{4} \approx \frac{1}{0.451}$
- c. $\frac{1}{\pi_0} = 1 + \frac{3}{4} + \frac{1}{2} + \frac{1}{4} \approx \frac{1}{0.4}$
- d. $\frac{1}{\pi_0} = 1 + \frac{1}{4} + \left(\frac{1}{4}\right)^2 + \left(\frac{1}{4}\right)^3 \approx \frac{1}{0.753}$
- e. $\frac{1}{\pi_0} = 1 + \frac{3}{4} + \left(\frac{1}{2}\right)^2 + \left(\frac{1}{4}\right)^3 \approx \frac{1}{0.496}$
- f. *none of the above*

___ 6. The operator will be busy what fraction of the time? *(choose nearest value)*

- a. 40%
- b. 45%
- c. 50%
- d. 60%
- e. 65%
- f. 75%

___ 7. What fraction of the time will the operator be busy but with no machine waiting to be serviced? *(choose nearest value)*

- a. 10%
- b. 20%
- c. 30%
- d. 40%
- e. 50%
- f. 60%

___ 8. Approximately 2.2 machines per hour require the operator's attention. What is the average length of time that a machine waits before the operator begins to ready the machine for the next job? *(select nearest value)*

- a. 0.1 hr. (i.e.,6 min.)
- b. 0.15 hr. (i.e., 9 min.)
- c. 0.2 hr. (i.e., 12 min.)
- d. 0.25 hr. (i.e., 15 min.)
- e. 0.3 hr. (i.e., 18 min.)
- f. greater than 0.33 hr. (i.e., >20 min.)

___ 9. What will be the utilization of this group of 3 machines? *(choose nearest value)*

- a. 50%
- b. 55%
- c. 60%
- d. 65%
- e. 70%
- f. *greater than* 75%