KEY!

Note: Change your VIEW (in the ribbon above) to DRAFT. Then point to an answer in a red block to see comments about it.

**DO NOT** TURN TO THE NEXT PAGE UNTIL YOU ARE INSTRUCTED TO DO SO!

Choose the correct (or best) answer on each multiple choice question. Read carefully, and check your answers. You are permitted to write whatever you wish on this exam, but the answers you record on your scantron will be considered your official answers to all questions.

Keep your eyes on your own paper. If you believe that someone sitting near you is cheating, raise your hand and quietly inform me of this. I'll keep an eye peeled, and your anonymity will be respected.

If any question seems unclear or ambiguous to you, raise your hand, and I will attempt to clarify it. Each question on this exam is worth 5 points.

Pledge: On my honor as a JMU student, I pledge that I have neither given nor received

unauthorized assistance on this examination.

Signature \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Questions 1 - 11 refer to the scenario described on the last page of this exam. You may, if you wish, CAREFULLY remove that page from your exam for ease in reference. Please note that the optimal representation will be needed only for question 10.

1. The total time required to complete "the job" is

a) 20.625 minutes b) 27.225 minutes c) 99 minutes d) 165 minutes e) 198 minutes

1. The shadow price of constraint 1 is in

a) crates/minute b) crates/dollar c) crates d) dollars/crate e) dollars/minute

1. One of the following statements is **true** about the optimal solution. Which one is it? (Note: don't waste time—no calculations are required.)
2. Conveyor AB runs for 6.6 minutes.
3. Department E receives an equal number of crates from B and from C.
4. Conveyor BD is used to capacity.
5. 192.06 crates are transferred from loading dock A.
6. All six conveyor belts are used to carry crates.
7. Suppose we were required to ship 149 crates to Department E, rather than 99. Which of the following statements does our sensitivity analysis allow us to conclude?
8. The cost the job will drop by $55.
9. The cost of the job will increase by $55.
10. The cost of the job will increase by $163.90.
11. The time required for the job will increase by 55 minutes.
12. Sensitivity does not allow us to conclude any of these statements.
13. Suppose we were required to ship 89 crates to Department D, rather than 99. Which of the following statements does our sensitivity analysis allow us to conclude?
14. The cost of the job would not change.
15. The cost of the job would drop by $8.40.
16. The cost of the job would increase by $8.40.
17. The time required for the job would not change.
18. Sensitivity does not allow us to conclude any of these statements.
19. In this MIN program, note that the OFCR of S2 extends to . This information, by itself, tells us that
20. S2 is nonbinding.
21. S2 could be made as large as we like without changing optimal schedule.
22. S2 could be made as large as we like without making the solution infeasible.
23. S2 cannot feasibly be bigger than 6.6.
24. S2 cannot feasibly be smaller than 6.6.
25. Currently, it costs $4.60 per minute just to run the conveyors in System II. Suppose that this cost were reduced to $0/minute. Then sensitivity analysis allows us to conclude that the optimal cost of completing the job
26. will drop by $4.60.
27. will drop by $30.36.
28. will increase by $30.36.
29. will decrease by the shadow prices of the S2 constraints.

e) None of these conclusions can be drawn.

1. Currently, Conveyor CD has no crate cost associated with its use. Suppose the crate cost for this conveyor rose to $0.50/crate. Then sensitivity allows us to conclude:
2. Cost to complete the job will remain unchanged.
3. Cost to complete the job will increase by $33.
4. We will ship less than 66 crates on conveyor CD.
5. We will ship less than 165 crates into Area C.
6. None of these conclusions can be drawn.
7. Suppose that the crate cost of Conveyor AC and Conveyor CD each increased by 19 cents per crate. Which of the following can be concluded by reference to our sensitivity analysis?
8. Optimal schedule does not change.
9. Optimal solution does not change.
10. Shadow prices do not change.
11. Reduced costs do not change.
12. None of these conclusions follow from our sensitivity analysis.
13. Suppose that Departments D and E each required 119 crates, rather than 99. Which of the following can be concluded by reference to our sensitivity analysis?
14. Optimal cost does not change.
15. Optimal schedule does not change.
16. Optimal costs increase by $22.
17. Optimal costs increase by $38.80.
18. None of these conclusions follow from our sensitivity analysis.
19. Suppose that the number of crates available at loading dock A drops by 4 crates. Which of the following statements is true about the optimal solution to this new situation?

a) AB = 33 b) AC = 165 c) SLK 5 = 0 d) optimal cost = $192.06 e) all of these are true.

Questions 12-15 constitute a matching problem. Each numbered entry provides information about some program constraint in an arbitrary MAX program. Given this information, choose the letter of the conclusion in the right hand column that follows from this information. No answer will be used more than once.

1. negative slack for a constraint A. the constraint is violated
2. zero slack for a constraint B. shadow price of the constraint is < 0
3. positive slack for a constraint C. the constraint is redundant
4. nonnegativity constraint D. shadow price of the constraint is 0
5. the constraint is binding
6. Let’s continue with the Chris Craft problem given on the last page of this exam. Which of the following changes could not be examined by using RHS or OFCR ranging?
7. changing the capacity (in crates/min) of conveyor AC
8. changing the supply (in crates) at loading dock A
9. changing the demand (in crates) in Department D
10. changing the demand (in crates) in both Department D and Department E
11. each of these changes could be investigated with sensitivity analysis
12. Continuing with Chris Craft: The allowable increase on the OFCR range of BE is not given on the printout. What should it be?
13. 0 b) 0.8 c) 1 d) 5.4 e) infinity
14. In a given linear program with the goal of maximizing profits over a 10 year period, one of the constraints says that the production capacity in the year 2000 must equal or exceed the production capacity for this year, 1999. The slack in this constraint would represent
15. the increase in profits from 1999 to 2000.
16. the additional profit which would be obtained if one more unit of production capacity were obtained in the year 2000.
17. the amount by which year 2000 production capacity exceeds the 1999 production capacity.
18. the production capacity in the year 2000.
19. (# of units of capacity in 1999) – (# of units of capacity in 2000)
20. Consider the program below. In this program, the shadow price of constraint 2 is:

MIN 2x + 1

subject to

1. x > 4

x > 0

a) 2 b) 1 c) 0 d) -1 e) -2

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Variables |  |  |  |  |  |  |  |  |  |  |
|  | AB | AC | BD | BE | CD | CE | S1 | S2 |  |  |  |
|  | 33 | 165 | 33 | 0 | 66 | 99 | 20.625 | 6.6 |  |  |  |
|  | Constraints |  |  |  |  |  |  |  | *LHS* |  | *RHS* |
| 1: AB Capacity | 1 | 0 | 0 | 0 | 0 | 0 | -10 | 0 | -173.25 | < | 0 |
| 2: AC Capacity | 0 | 1 | 0 | 0 | 0 | 0 | -8 | 0 | 0 | < | 0 |
| 3: BD Capacity | 0 | 0 | 1 | 0 | 0 | 0 | 0 | -5 | 0 | < | 0 |
| 4: BE capacity | 0 | 0 | 0 | 1 | 0 | 0 | 0 | -5 | -33 | < | 0 |
| 5: CD capacity | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -10 | 0 | < | 0 |
| 6: CE Capacity | 0 | 0 | 0 | 0 | 0 | 1 | 0 | -20 | -33 | < | 0 |
| 7: Supply | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 198 | < | 300 |
| 8: Node B | -1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | = | 0 |
| 9: Node C | 0 | -1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | = | 0 |
| 10: D Demand | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 99 | > | 99 |
| 11: E Demand | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 99 | > | 99 |
| Cost | 0.5 | 0.25 | 0.1 | 0.8 | 0 | 0.6 | 2 | 4.6 | 192.06 | = | Cost |

*Excel Formulation of Chris Craft ProblemSWITCH VIEW FROM DRAFT TO PRINT LAYOUT TO SEE GRAPHIC, THEN CHANGE BACK TO DRAFT!*



The Chris Craft Company has three hundred identical crates of craft materials at its loading dock, and wishes to move some of these crates to where they are needed. Currently, Department D and Department E each need at least 99 crates. Crates are moved within the factory via a series of conveyor belts. The conveyor belts run at different speeds, and have different operations costs. The details of each conveyor appear in the diagram above. Conveyor AB, for example, can carry up to 10 crates/minute from the loading dock to Inventory Area B. It costs Chris Craft $1 for every minute that Conveyor AB is running, regardless of whether it is actually being used. In addition, each crate transported by Conveyor AB costs Chris Craft an additional 50 cents.

Two power switches control which conveyor belts are running at any given time. One switch activates/deactivates the System I conveyors—those belts which run from the loading dock to the inventory areas. The other switch activates/deactivates the System II conveyors—the four conveyor belts connecting the inventory areas with departments D and E. Since power considerations preclude both systems operating simultaneously, all System I conveyors are activated for a time, then System I is shut down, and then all System II conveyors are activated. At the end of this time, all crates should be at their destinations. Chris Craft wishes to minimize the cost "**the job**"—the total cost of transporting the needed crates.

**This is the same problem appearing on your first exam, with two changes.** The Exam I problem required that no packages could be loaded on a belt during its last 1 minute of operation. This was to give the belts time to clear. We ignore the complication of clearing time here. You may wish to imagine pneumatic conveyors that "shoot" the package to the other end of the conveyor in the blink of an eye. We also changed the capacity of conveyors BC and BD from the values given in the original problem.

The decision variables for this problem are as follows:

S1 = # of minutes that System I is in operation.

S2 = # of minutes that System II is in operation.

AB = # of crates transported on Conveyor AB

AC, BD, BE, CD, and CE are defined in parallel fashion to the definition of AB.

The EXCEL printout for this problem appears on the other side of this page. Study it carefully.

Constraints 1-6 say that no conveyor is used beyond its capacity. (It may be easier to interpret these constraints as AB < 10 S1, and so on. The **capacity** of a conveyor is the maximum number of crates it could carry, given its time in operation.) Constraint 7 says that we don't exceed the supply of crates at the loading dock. 8 and 9 assure that what goes into an inventory area matches what leaves it. 10 and 11 say that we must meet or exceed the demands for departments D and E.

MIN 0.5 AB + 0.25 AC + 0.1 BD + 0.8 BE + 0.6 CE + 2 S1 + 4.6 S2

SUBJECT TO

1) AB - 10 S1 <= 0 7) AB + AC <= 300

2) AC - 8 S1 <= 0 8) - AB + BD + BE = 0

3) BD - 5 S2 <= 0 9) - AC + CE + CD = 0

4) BE - 5 S2 <= 0 10) BD + CD >= 99

5) CD - 10 S2 <= 0 11) BE + CE >= 99

6) CE - 20 S2 <= 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Adjustable Cells | | |  |  |  |  |  |
|  |  |  | **Final** | **Reduced** | **Objective** | **Allowable** | **Allowable** |
|  | **Cell** | **Name** | **Value** | **Cost** | **Coefficient** | **Increase** | **Decrease** |
|  | $B$3 | AB | 33 | 0 | 0.5 | 0.36 | 0.2 |
|  | $C$3 | AC | 165 | 0 | 0.25 | 0.2 | 0.36 |
|  | $D$3 | BD | 33 | 0 | 0.1 | 0.36 | 1.02 |
|  | $E$3 | BE | 0 | 0.2 | 0.8 | deleted | 0.2 |
|  | $F$3 | CD | 66 | 0 | 0 | 1.02 | 0.36 |
|  | $G$3 | CE | 99 | 0 | 0.6 | 0.2 | 1.1 |
|  | $H$3 | S1 | 20.625 | 0 | 2 | 1.6 | 2 |
|  | $I$3 | S2 | 6.6 | 0 | 4.6 | 1E+30 | 3.6 |
|  |  |  |  |  |  |  |  |
| Constraints | | |  |  |  |  |  |
|  |  |  | **Final** | **Shadow** | **Constraint** | **Allowable** | **Allowable** |
|  | **Cell** | **Name** | **Value** | **Price** | **R.H. Side** | **Increase** | **Decrease** |
|  | $J$5 | 1: AB Capacity LHS | -173.25 | 0 | 0 | 1E+30 | 173.25 |
|  | $J$6 | 2: AC Capacity LHS | 0 | -0.25 | 0 | 138.6 | 1E+30 |
|  | $J$7 | 3: BD Capacity LHS | 0 | -0.24 | 0 | 24.75 | 49.5 |
|  | $J$8 | 4: BE capacity LHS | -33 | 0 | 0 | 1E+30 | 33 |
|  | $J$9 | 5: CD capacity LHS | 0 | -0.34 | 0 | 24.75 | 198 |
|  | $J$10 | 6: CE Capacity LHS | -33 | 0 | 0 | 1E+30 | 33 |
|  | $J$11 | 7: Supply LHS | 198 | 0 | 300 | 1E+30 | 102 |
|  | $J$12 | 8: Node B LHS | 0 | -0.5 | 0 | 33 | 102 |
|  | $J$13 | 9: Node C LHS | 0 | -0.5 | 0 | 138.6 | 102 |
|  | $J$14 | 10: D Demand LHS | 99 | 0.84 | 99 | 102 | 24.75 |
|  | $J$15 | 11: E Demand LHS | 99 | 1.1 | 99 | 33 | 99 |