Practice Problems for Pulse-Check 1

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1. In a standard LP of the form $\max c^\top x$ subject to $Ax \leq b$, $x \geq 0$, the feasible region is:

   (A) Always unbounded
   (B) A polytope (bounded convex polyhedron) or empty
   (C) A convex polyhedron (possibly unbounded) or empty
   (D) Always a single point

2. You want to maximize profit from two products. Each unit of Product A yields \$5 and each unit of Product B yields \$8. Which objective function is correct?

   (A) $\min 5x_a + 8x_b$
   (B) $\max 5x_a + 8x_b$
   (C) $\max 8x_a + 5x_b$
   (D) $\max 5x_a - 8x_b$

3. If Gurobi reports a model is "infeasible," this means:

   (A) The objective is unbounded
   (B) No solution satisfies all constraints simultaneously
   (C) There are too many variables
   (D) The optimal value is zero

4. If Gurobi reports a model is "unbounded," this means:

   (A) There is no feasible solution
   (B) The feasible region is empty
   (C) The objective can be made arbitrarily good (large for max, small for min)
   (D) The solver ran out of time

5. In a 2-variable LP, the optimal solution (if it exists and the LP is bounded) is found at:

   (A) The center of the feasible region

   (B) A vertex (corner point) of the feasible region

   (C) The midpoint of a constraint

   (D) Any interior point

6. The simplex algorithm moves from one solution to the next by:

   (A) Jumping to random feasible points

   (B) Moving along edges of the polytope from vertex to vertex

   (C) Searching the entire interior

   (D) Enumerating all possible solutions

7. A Basic Feasible Solution (BFS) is defined by:

   (A) A solution where all variables are positive

   (B) A vertex of the feasible region where n linearly independent constraints are tight

   (C) Any feasible solution

   (D) The solution with the largest objective value

8. The strong duality theorem states that if both the primal and dual have feasible solutions, then:

   (A) The primal optimal is strictly less than the dual optimal

   (B) The primal optimal equals the dual optimal

   (C) The dual is always infeasible

   (D) One of them must be unbounded

9. In a maximization LP, the dual of the problem is:

   (A) Also a maximization problem

   (B) A minimization problem

   (C) An integer program

   (D) Undefined

10. A shadow price (dual variable) for a constraint tells you:

(A) The cost of adding a new variable
(B) The rate of change of the optimal objective per unit increase in the constraint's RHS
(C) Whether the constraint should be removed
(D) The slack in the constraint

11. If a constraint has positive slack (i.e. is not tight) at the optimum, its shadow price is:

(A) Positive
(B) Negative
(C) Zero
(D) Undefined

12. Complementary slackness says that at optimality:

(A) All constraints are tight
(B) If a primal constraint has slack (i.e. is not tight), the corresponding dual variable is zero (and vice versa)
(C) All dual variables are positive
(D) The primal and dual have different optimal values

13. The LP relaxation of a binary integer program is obtained by:

(A) Removing all constraints
(B) Replacing integer/binary restrictions with continuous bounds (e.g., $0 \leq x \leq 1$)
(C) Adding more integer variables
(D) Doubling all constraints

14. For a minimization IP, the LP relaxation optimal value LP^* satisfies:

(A) $LP^* \geq IP^*$
(B) $LP^* \leq IP^*$
(C) $LP^* = IP^*$ always
(D) No relation between them

15. The Assignment Problem's LP relaxation is special because:

(A) It is always infeasible
(B) It always gives an integer optimal solution (the LP relaxation is exact)

(C) It has an unbounded integrality gap

(D) It requires exponentially many constraints

16. For the Maximum Independent Set problem (maximum number of vertices where no pair has an edge), the LP relaxation:

    (A) Is always exact

    (B) Can have an arbitrarily bad integrality gap

    (C) Always finds the optimal integer solution

    (D) Has no feasible LP solution

17. In Branch and Bound for a minimization IP, the LP relaxation provides:

    (A) An upper bound on the IP optimal

    (B) A lower bound on the IP optimal

    (C) The exact IP optimal

    (D) No useful information

18. In Branch and Bound, a node is pruned when:

    (A) The LP relaxation is feasible and fractional

    (B) The LP relaxation bound is worse than the best known integer solution, or the LP is infeasible, or the LP solution is integer

    (C) The LP relaxation is better than all other nodes

    (D) It is the root node

19. In Branch and Bound, "branching" means:

    (A) Adding a new variable to the model

    (B) Splitting a subproblem by fixing a fractional variable to 0 or 1 (or $\leq k$ and $\geq k+1$)

    (C) Removing a constraint

    (D) Restarting the solver

20. A general integer variable $x \in \{0, 1, 2, \ldots, 7\}$ can be encoded in binary using (less is better):

    (A) 7 binary variables

    (B) 3 binary variables

    (C) 1 binary variable

(D) 8 binary variables

21. In a 0–1 Knapsack problem, each variable x_i represents:

    (A) The weight of item i
    (B) Whether item i is selected (1) or not (0)
    (C) The profit of item i
    (D) The capacity remaining

22. Naïve enumeration of a binary IP with n variables checks at most:

    (A) n solutions
    (B) 2^n solutions
    (C) n^2 solutions
    (D) $n!$ solutions

23. In a maximization IP, if the LP relaxation value of a node is 15.3 and the best known integer solution has value 16, this node is:

    (A) Pruned because $15.3 < 16$
    (B) Not pruned; we keep exploring
    (C) The new incumbent
    (D) Infeasible

24. A "strong" LP relaxation for an IP means:

    (A) The LP relaxation is far from the IP optimum
    (B) The LP relaxation value is close to the IP optimum
    (C) The LP has many constraints
    (D) The LP takes a long time to solve

25. Adding valid inequalities (like cover inequalities) to an IP typically:

    (A) Makes the LP relaxation weaker
    (B) Makes the LP relaxation tighter (stronger)
    (C) Removes feasible integer solutions
    (D) Makes the problem infeasible

26. The tradeoff when adding many cuts to strengthen an IP formulation is:

(A) Stronger LP → fewer B&B nodes, but each LP solve is larger/slower

(B) Stronger LP → more B&B nodes and faster LP solves

(C) No tradeoff; more cuts is always better

(D) Cuts make the problem infeasible

27. Big-M modeling is used to:

(A) Make the LP relaxation exact

(B) Encode logical implications and disjunctions using binary variables

(C) Remove all integer variables

(D) Guarantee polynomial solve time

28. When encoding "if $y = 1$ then $x \leq 5$" using Big-M, the correct constraint is:

(A) $x \leq 5$

(B) $x \leq 5 + M(1 - y)$ where M is a large valid upper bound on x.

(C) $x \geq 5y$

(D) $x = 5y$

29. Choosing M too large in a Big-M constraint causes:

(A) The problem to be infeasible

(B) A weak LP relaxation (poor bounds)

(C) The problem to be exact

(D) Faster solve times

30. SOS1 (Special Ordered Set of Type 1) means:

(A) All variables must be positive

(B) At most one variable in the set can be nonzero

(C) Exactly two variables must be nonzero

(D) Variables must be binary

31. To encode the logical OR "$x_1 = 1$ OR $x_2 = 1$" with binary variables:

(A) $x_1 + x_2 = 0$

(B) $x_1 + x_2 \geq 1$

(C) $x_1 + x_2 \leq 1$

(D) $x_1 \cdot x_2 = 1$

32. To encode "at most one of x_1, x_2, x_3 is selected" with binary variables:

(A) $x_1 + x_2 + x_3 \geq 1$
(B) $x_1 + x_2 + x_3 \leq 1$
(C) $x_1 + x_2 + x_3 = 3$
(D) $x_1 \cdot x_2 \cdot x_3 \leq 1$

33. To encode the implication "$x_1 = 1 \Rightarrow x_2 = 1$" with binary variables:

(A) $x_1 \leq x_2$
(B) $x_1 \geq x_2$
(C) $x_1 + x_2 = 1$

34. In the arc-based TSP formulation, binary variable $x_{ij} = 1$ means:

(A) City i is visited before city j
(B) The tour travels directly from city i to city j
(C) Cities i and j are the same
(D) City i is not visited

35. Degree constraints in the TSP formulation require that:

(A) Every city is visited at most once
(B) Exactly one arc enters and one arc leaves each city
(C) The tour has minimum length
(D) All arcs are used

36. Subtour elimination constraints in TSP are needed because:

(A) The degree constraints alone allow disconnected subtours.
(B) The objective is nonlinear
(C) The variables are continuous
(D) The graph is bipartite

37. The MTZ formulation eliminates subtours by introducing:

(A) Exponentially many constraints

(B) Ordering variables u_i that force a single connected tour via Big-M-style constraints
(C) Quadratic number of new variables.
(D) A second objective function

38. Spatial Branch and Bound is used for:

    (A) Linear programs only
    (B) Convex quadratic programs only
    (C) Nonconvex MINLPs where the feasible region or objective is nonconvex

39. McCormick envelopes are used in spatial B&B to:

    (A) Solve TSP
    (B) Create convex relaxations of bilinear terms (e.g., $w = xy$)
    (C) Eliminate integer variables
    (D) Find dual variables

40. The Gurobi NonConvex parameter allows Gurobi to:

    (A) Solve only linear programs
    (B) Handle nonconvex quadratic objectives/constraints via spatial branch-and-bound
    (C) Ignore all constraints
    (D) Convert the problem to a network flow

41. Row generation (constraint generation) is useful when:

    (A) The LP has very few constraints
    (B) The LP has exponentially many constraints and we add only violated ones iteratively
    (C) All constraints are always active
    (D) The LP is infeasible

42. A separation oracle in row generation:

    (A) Removes variables from the LP
    (B) Given a candidate solution, finds a violated constraint or certifies that none exist
    (C) Solves the LP to optimality in one step
    (D) Converts an LP to an IP

Solutions:

1. (C)
2. (B)
3. (B)
4. (C)
5. (B)
6. (B)
7. (B)
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10. (B)
11. (C)
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38. (C)
39. (B)
40. (B)
41. (B)
42. (B)