Written Analysis

1. **Provide an optimal plan for Problems 1, 2, and 3.**
    - Problem 1 (Plan Length 6):
        - Load(C1, P1, SFO)
        - Load(C2, P2, JFK)
        - Fly(P1, SFO, JFK)
        - Fly(P2, JFK, SFO)
        - Unload(C1, P1, JFK)
        - Unload(C2, P2, SFO)

    - Problem 2 (Plan Length 9):
        - Load(C3, P3, ATL)
        - Fly(P3, ATL, SFO)
        - Unload(C3, P3, SFO)
        - Load(C2, P2, JFK)
        - Fly(P2, JFK, SFO)
        - Unload(C2, P2, SFO)
        - Load(C1, P1, SFO)
        - Fly(P1, SFO, JFK)
        - Unload(C1, P1, JFK)

    - Problem 3 (Plane Length 12) :
        - Load(C2, P2, JFK)
        - Load(C1, P1, SFO)
        - Fly(P2, JFK, ORD)
        - Load(C4, P2, ORD)
        - Fly(P2, ORD, SFO)
        - Unload(C2, P2, SFO)
        - Unload(C4, P2, SFO)
        - Fly(P1, SFO, ATL)
        - Load(C3, P1, ATL)
        - Fly(P1, ATL, JFK)
        - Unload(C1, P1, JFK)
        - Unload(C3, P1, JFK)

Problem 2-4:

Problem 1

Heuristics	Pan Length	Time Elapsed	Expansions	Goal Tests	New Nodes
Bread First	6	0.02435	43	56	180
Bread First Tree	6	0.78519	1458	1459	5960
Depth First Graph	12	0.00645	12	13	48
Depth Limited	50	0.07245	101	271	414
Uniform Cost	6	0.04360	55	57	224
Recursive Best First	6	2.24563	4229	4230	17029
Greedy Best First	7	0.01217	7	9	28
A* Ignore_Preconditions	6	0.04927	41	43	170
A* PG_LevelSum	6	1.53480	11	13	50

Problem 2

Heuristics	Pan Length	Time Elapsed	Expansions	Goal Tests	New Nodes
Bread First	9	7.08703	2401	4672	31049
Depth First Graph	346	1.30887	350	351	3142
Uniform Cost	9	10.3134	4761	4763	43206
A* Ignore_Preconditions	9	6.47350	1450	1452	13303
A* levelsum	9	247.90433	111	113	1001

Problem 3

Heuristics	Pan Length	Time Elapsed	Expansions	Goal Tests	New Nodes
Bread First	12	33.30111	14491	17947	128184
Depth First Graph	1878	15.98957	1948	1949	16253
Uniform Cost	12	39.80203	17783	17785	155920
A* Ignore_Preconditions	12	15.505	5003	5005	44586
A* levelsum	21	1739.3099	435	437	3934

2. **Compare and contrast non-heuristic search result metrics (optimality, time elapsed, number of node expansions) for Problems 1,2, and 3. Include breadth-first, depth-first, and at least one other uninformed non-heuristic search in your comparison; Your third choice of non-heuristic search may be skipped for Problem 3 if it takes longer than 10 minutes to run, but a note in this case should be included.**

I am comparing Breadth First, Depth First and Uniform Cost for Problem 1-3. Uniform cost and Breadth first both reached the optimal plan for all problems, but depth first search never was able to reach the optimal plan. This issue was discussed as a problem with Depth First search in the lecture. However, I do observe that Depth first search expands to fewer nodes and takes less time to reach a solution. This is also an advantage of depth first search mentioned in the lecture.

3. **Compare and contrast heuristic search result metrics using A* with the "ignore preconditions" and "level-sum" heuristics for Problems 1, 2, and 3.**
   Both heuristics reached the optimal plan for Problem 1 and 2, but level-sum failed for problem 3. Another noticeable difference is that level-sum takes significantly larger time to compute, while expands to fewer nodes.

4. **What was the best heuristic used in these problems? Was it better than non-heuristic search planning methods for all problems? Why or why not?**

   The best heuristic is Ignore_Preconditions. While non-heuristics like Breadth First takes less time to reach the optimal solution for simpler problems like Problem 1. Depth First would be a bed choice for planning problems because it rarely reaches the optimal plan for these 3 questions. Considering the complexity of real-world planning problems, Depth First is far less likely to reach the optimal plan either. Ignore_Preconditions is much faster for more complicated problems, such as Problem 2 and 3 than Breadth First and Uniform Cost. Also, because Ignore_Predcontion is able to explore much more nodes than level-sum, it guaranteed to reach the optimal plan for all 3 problems while level-sum failed for problem 3.

5. **Provide tables or other visual aids as needed for clarity in your discussion.**