Air Cargo Problem 1

Solving Air Cargo Problem 1 using breadth_first_search...

```
Expansions   Goal Tests   New Nodes
    43          56         180
```

```
Plan length: 6  Time elapsed in seconds: 0.029625833994941786
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
```

Solving Air Cargo Problem 1 using depth_limited_search...

```
Expansions   Goal Tests   New Nodes
   101         271         414
```

```
Plan length: 50  Time elapsed in seconds: 0.08900232901214622
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
```

```
Load(C1, P1, SFO)
Unload(C1, P1, SFO)
Load(C1, P1, SFO)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
```

Solving Air Cargo Problem 1 using uniform_cost_search...

```
Expansions   Goal Tests   New Nodes
    55          57         224

Plan length: 6  Time elapsed in seconds: 0.03832069301279262
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)
```

Solving Air Cargo Problem 1 using astar_search with h_ignore_preconditions...

```
Expansions   Goal Tests   New Nodes
    41          43         170

Plan length: 6  Time elapsed in seconds: 0.03655146699748002
Load(C1, P1, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
```

Solving Air Cargo Problem 1 using astar_search with h_pg_levelsum...

```
Expansions   Goal Tests   New Nodes
    11          13          50

Plan length: 6  Time elapsed in seconds: 1.037896752008237
Load(C1, P1, SFO)
Fly(P1, SFO, JFK)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)
```

Air Cargo Problem 2

Solving Air Cargo Problem 2 using breadth_first_search...

```
Expansions   Goal Tests   New Nodes
   3343        4609       30509

Plan length: 9  Time elapsed in seconds: 12.580524274002528
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Load(C3, P3, ATL)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
```

```
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
```

Solving Air Cargo Problem 2 using depth_first_graph_search...

```
Expansions   Goal Tests   New Nodes
   624         625         5602

Plan length: 619  Time elapsed in seconds: 3.2110631510149688
```

Whole output is too long only put a small portion of the output

```
Fly(P3, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P3, SFO, JFK)
Fly(P1, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P3, JFK, ATL)
……
Fly(P1, ATL, JFK)
Fly(P3, SFO, JFK)
Unload(C3, P2, SFO)
```

Solving Air Cargo Problem 2 using uniform_cost_search...

```
Expansions   Goal Tests   New Nodes
   4853        4855       44041

Plan length: 9  Time elapsed in seconds: 10.684873781981878
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Load(C3, P3, ATL)
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
Unload(C2, P2, SFO)
Unload(C1, P1, JFK)
```

Solving Air Cargo Problem 2 using astar_search with h_ignore_preconditions...

```
Expansions   Goal Tests   New Nodes
   1450        1452       13303

Plan length: 9  Time elapsed in seconds: 3.9316946259932593
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)
```

Solving Air Cargo Problem 2 using astar_search with h_pg_levelsum...

```
Expansions   Goal Tests   New Nodes
    86          88         841

Plan length: 9  Time elapsed in seconds: 180.08348978799768
```

```
Load(C1, P1, SFO)
Fly(P1, SFO, JFK)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Load(C3, P3, ATL)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
Unload(C2, P2, SFO)
Unload(C1, P1, JFK)
```

Air Cargo Problem 3

Solving Air Cargo Problem 3 using breadth_first_search...

```
Expansions   Goal Tests   New Nodes
  14663       18098       129631

Plan length: 12  Time elapsed in seconds: 92.47053823698661
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P2, JFK, ORD)
Load(C4, P2, ORD)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P1, ATL, JFK)
Unload(C1, P1, JFK)
Unload(C3, P1, JFK)
Fly(P2, ORD, SFO)
Unload(C2, P2, SFO)
Unload(C4, P2, SFO)
```

Solving Air Cargo Problem 3 using depth_first_graph_search...

```
Expansions   Goal Tests   New Nodes
   408         409         3364

Plan length: 392  Time elapsed in seconds: 2.1217825079802424

Whole output is too long only put a small portion of the output

Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C2, P1, JFK)
```

Solving Air Cargo Problem 3 using uniform_cost_search...

```
Expansions   Goal Tests   New Nodes
  18223       18225       159618

Plan length: 12  Time elapsed in seconds: 45.88655267699505
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P2, JFK, ORD)
Load(C4, P2, ORD)
Fly(P2, ORD, SFO)
```

```
Fly(P1, ATL, JFK)
Unload(C4, P2, SFO)
Unload(C3, P1, JFK)
Unload(C2, P2, SFO)
Unload(C1, P1, JFK)
```

Solving Air Cargo Problem 3 using astar_search with h_ignore_preconditions...

```
Expansions   Goal Tests   New Nodes
   5040        5042       44944

Plan length: 12  Time elapsed in seconds: 14.860786504985299
Load(C2, P2, JFK)
Fly(P2, JFK, ORD)
Load(C4, P2, ORD)
Fly(P2, ORD, SFO)
Unload(C4, P2, SFO)
Load(C1, P1, SFO)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P1, ATL, JFK)
Unload(C3, P1, JFK)
Unload(C2, P2, SFO)
Unload(C1, P1, JFK)
```

Solving Air Cargo Problem 3 using astar_search with h_pg_levelsum...

```
Expansions   Goal Tests   New Nodes
   325         327         3002

Plan length: 12  Time elapsed in seconds: 1136.334524957987
Load(C2, P2, JFK)
Fly(P2, JFK, ORD)
Load(C4, P2, ORD)
Fly(P2, ORD, SFO)
Load(C1, P1, SFO)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P1, ATL, JFK)
Unload(C4, P2, SFO)
Unload(C3, P1, JFK)
Unload(C2, P2, SFO)
Unload(C1, P1, JFK)
```

Analysis

Using Breadth-First Search we are able to find the shortest path to the goal compare to Depth-First Search which ends up taking more paths to find the goal because it searches down a path till it reaches the leaf node and backtracks. Although both finds the goal we can see that BFS actually is more optimal than DFS but DFS is more efficient in terms of time. Depending on what you are looking for in the results, you can use DFS for time efficiency and BFS for a more optimal search.

A* search finds optimal solution to problems as long as the heuristic is admissible which means it never overestimates the cost of the path to the from any given node. Being that we used two heuristic, ignore precondition and level sum, which allow A* search to be optimal. Heuristics allows us to go through the search more efficiently but it does not always mean it does it in a timely fashion. We can see that for optimization we should choose the level sum heuristic but in terms of time complexity we would go with ignore precondition.

Best answer for each problem:

Problem 1
BFS, Uniform, and A* with ignore precondition all gives us similar results of optimal plan lengths and time efficiency.

Problem 2
DFS and A* with ignore precondition gave us the best results with a plan length of 12 and under 4 second of elapsed time.

Problem 3
In terms of optimal and time efficiency, we can see that A* with ignore precondition gives us the best results

In conclusion I believe for an optimal results and time efficiency we should use A* search for these problems as it gives us consistent results across all three problems. Heuristic searches gives advantage over BFS and uniform searches because of how it gives us an idea of what to search.