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Instructions

Choose ONE of the three questions below and answer it using simulation.
Your submission must include:

- Well-commented code (I should be able to follow your logic)
- A written analysis that answers the actual questions being asked (not just reporting numbers)
- At least one plot that directly supports a conclusion
- At least one sensitivity analysis (change an assumption and explain what changes)
- A clear recommendation in plain English, supported by your simulation results

You may make additional reasonable assumptions, but you must state and justify them.

Required (for any problem you choose):

Make one recommendation that optimizes something under a constraint.

- Queueing: minimize total cost *or* meet a service-level constraint
- Inventory: maximize profit while accounting for salvage/stockouts (or another realistic feature)
- Reliability: maximize uptime per dollar under a budget constraint

Question 1: Urgent Care Center Queueing Systems

You operate an urgent care center that:

- Opens at 8am and closes at 5pm
- Customer arrivals follow a Poisson process
  - Rate = 4 per hour, except 12–1pm, when rate = 6 per hour
- Service times are i.i.d. random variables on the positive real line *(you must choose and justify a service-time distribution)*

You have 2 servers.

You are considering three queuing systems:

1. Single pooled line with parallel servers
2. Tandem service (In-N-Out style): customers must complete service at Server 1, then Server 2

3. Separate lines, one per server (grocery-store style)

Core Tasks

- Simulate 1 work week (5 days).
- Repeat the week simulation 7 times and average results.
- Estimate and report:
  - Mean waiting time
  - Distribution of waiting times (not just the mean)
- Compare the systems.

Decision Requirement (required)

Assume:

- Waiting cost = \$0.50 per customer-minute
- Server cost = \$30 per hour per server

Your task is to:

- Choose the "best" system and clearly define what "best" means
- Report the total expected daily cost
- Make a clear operational recommendation

Add ONE realism feature (choose one)

Pick one of the following additions and incorporate it in your model:

A. Staffing tradeoff: allow 2 vs 3 servers during 12–1pm and choose the best option under total cost

B. Service-level constraint: ensure P(wait $>$ 20 minutes) $=<$ 0.05. If unmet, propose what change makes it feasible

C. Abandonment: customers leave if their predicted wait exceeds a random patience threshold; compare throughput + lost customers + revenue

Difficulty Options (choose ONE)

Easy

- All servers have the same service-time distribution
- Compare only System 1 (pooled) vs System 2 (tandem)

Medium

- Servers have different service rates

- Explain why tandem service behaves differently when servers are unbalanced
- Does it matter where the "slow" server is placed?

Hard

- In System 3 (separate lines), allow customers to switch lines
- Compare outcomes with and without switching

Hardest

- Use 3 servers, each with a different service-time distribution or rate
- Use a nonhomogeneous Poisson process for arrivals (beyond a single lunch rush)
- Allow line-switching in System 3
- Optimize system choice and staffing level during the busy period

Note: If you want a concrete service-time option, you may use either:

- Lognormal service times (e.g., mean 10 min, sd 8 min), or
- A mixture model (e.g., 80% "quick" mean 6 min, 20% "long" mean 20 min)