PART A

(1/1 point)

Factory F produces three different products $P = \{1, 2, 3\}$ with a single machine. The factory starts operations at 9 AM every morning and ends operations at 5 PM. (Each day has 480 minutes of work.) The machine is configured differently for the three products. To configure the machine to start producing product $i \in \{1, 2, 3\}$ requires a set-up time (see Table 1). If, for example, the machine were producing product 2, and we would like to switch production to product 1, we would require 45 minutes of set-up time. At the beginning of each day, the machine has to be configured (requires set-up time) regardless of what the last item produced was on the previous day.

The time horizon for this problem is four days. At the end of each day, the factory must meet the demand for each product given in Table 1. If there are items remaining after meeting demand, these items are stored in inventory at a cost of h_i per unit for product i (see Table 1).

In the following parts, let x_{it} denote the time the machine spends on day t producing item i for $i \in P$, and for $t \in \{1, 2, 3, 4\}$. Let y_{it} be the number of units of item i produced on day t, and 0 otherwise. Fractional production units are allowed. Also, the time spent on a day producing an item can be fractional. Let z_{it} be the variable that tells us if we set up the machine to produce item i in day t. Let s_{it} be the amount of product i that is stored in inventory from the end of day t to the start of day $t + 1$. We require that $s_{i4} = 0$ for each $i \in P$, which means there is no inventory left at the end of day 4. There is no inventory at the beginning of the first day ($s_{i0} = 0$ for each $i \in P$).

	Set-up Time [min]	Price [$]	Production Rate [units/min]	Inventory Cost [$]	Demand Day 1 [units]	Demand Day 2 [units]	Demand Day 3 [units]	Demand Day 4 [units]
Product 1	45	50	5	18	400	600	200	800
Product 2	60	70	4	15	240	440	100	660
Product 3	100	120	2	25	80	120	40	100

Table 1:

Formulate a mixed integer program that maximizes the total profits. We let d_{it} refer to the demand of item i in day t, and we let r_i refer to the production rate of product i. These are parameters, not decision variables).

The objective function corresponds to maximizing the total revenue minus the inventory costs. It takes the following form: $\sum_{i=1}^{3} \sum_{t=1}^{4} a_i d_{it} - \sum_{i=1}^{3} \sum_{t=1}^{4} b_i s_{it}$. One can determine a_i and b_i for $i = 1 \text{ to } 3$ from the data.

What is $a_1 + a_2 + a_3 + b_1 + b_2 + b_3$? Error checking hint: the answer is between 290 and 309.

298 ✔

298

You have used 1 of 3 submissions

PART B

(2/2 points)

The constraint for machine usage time limit for day t in minutes is $az_{1t} + bz_{2t} + cz_{3t} + d\sum_{i=1}^{3} x_{it} \leq e$. You can obtain the coefficients by looking at the data. What is $a + b + c + d + e$? Error checking hint. The value is between 680 and 699.

686 ✔

686

You have used 1 of 3 submissions

PART C

(3/3 points)

The inventory of item i from at the end of day t is equal to the initial stock of day t - 1 plus the production in day t minus the demand in day t.

Choose all necessary constraint(s) to model inventory balance below. Your answer should include four sets of constraints.

- [ ] $s_{it-1} + y_{it} = s_{it}, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$
- [x] $s_{it-1} + y_{it} - d_{it} = s_{it}, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$
- [ ] $s_{it-1} + y_{it} + d_{it} = s_{it}, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$
- [ ] $d_{it} = 0, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$
- [x] $s_{i0} = 0, \forall i = 1, \ldots, 3$
- [ ] $s_{i1} \leq 0, \forall i = 1, \ldots, 3$
- [ ] $s_{i4} \leq 0, \forall i = 1, \ldots, 3$
- [x] $s_{i4} = 0, \forall i = 1, \ldots, 3$
- [x] $s_{it} \geq 0, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$

✔

You have used 1 of 3 submissions

PART D

(1/1 point)

Please select the remaining constraint(s) that are needed for the formulation to be correct. Select 4 sets of constraints.

- [ ] $x_{it} \geq Mz_{it}, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$
- [x] $x_{it} \leq Mz_{it}, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$
- [ ] $x_{it} = Mz_{it}, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$
- [x] $y_{it} = r_i x_{it}, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$
- [ ] $y_{it} \geq r_i x_{it}, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$
- [ ] $x_{it} = r_i y_{it}, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$
- [ ] $x_{it} \geq r_i y_{it}, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$
- [x] $z_{it} \in \{0, 1\}$
- [x] $x_{it}, y_{it} \geq 0, \forall t = 1, \ldots, 4, i = 1, \ldots, 3$

✔

You have used 1 of 3 submissions

PART E

(1/1 point)

Solve the production problem you formulated from parts (a) to (d) using Julia and JuMP. What's the optimal objective value (net revenue minus inventory costs)? Error checking hint. The value is between 238000 amd 239000.

238350 ✔

$\mathbf{238350}$

You have used 1 of 3 submissions

PART F

(1/1 point)

Using the original given values, consider that it is possible to have a Super Production (SP) day in which there are an extra 2 hours in the day. The extra two hours costs $50 because of increased labor costs. The factory can have up to two SP days out of four, but the two days cannot be consecutive. Formulate the modified machine scheduling problems as a mixed integer linear program. Let u_t for t = 1, 2, 3, 4 be the extra decision variables. $u_t = 1$ means that day t is a super production day; $u_t = 0$, otherwise.

The new objective function we want to maximize for total profit is:
$\sum_{i=1}^{3} \sum_{t=1}^{4} a_i d_{it} - \sum_{i=1}^{3} \sum_{t=1}^{4} b_i s_{it} - c \sum_{t=1}^{4} u_t.$

What is c? There is no error checking hint for this problem.

50 ✔

50

You have used 1 of 3 submissions

PART G

(1/1 point)

Choose the correct 4 sets of constraints that should be added (replaced):

- [ ] $45z_{1t} + 60z_{2t} + 100z_{3t} + \sum_{i=1}^{3} x_{it} \leq 480 + u_t, \forall t = 1, \ldots, 4$
- [x] $45z_{1t} + 60z_{2t} + 100z_{3t} + \sum_{i=1}^{3} x_{it} \leq 480 + 120u_t, \forall t = 1, \ldots, 4$
- [ ] $\sum_{t=1}^{4} u_t \geq 2$
- [x] $\sum_{t=1}^{4} u_t \leq 2$
- [ ] $u_t \leq 1, \forall t = 1, \ldots, 4$
- [ ] $u_t = 0, \forall t = 1, \ldots, 4$
- [x] $u_{t-1} + u_t \leq 1, \forall t = 2, \ldots, 4$

- [x] $u_t \in \{0,1\}, \forall t = 1, \ldots, 4$

✔

You have used 1 of 3 submissions

PART H

(1/1 point)

Solve the production problem under Super Production Days you formulated above in PARTS A to G using Julia and JuMP. What's the optimal objective value? Error checking hint: it is between 240000 and 241900.

241000 ✔

$\mathbf{241000}$

Hint: If you change time limit without SP day to 500 minutes, optimal value should be 241000.

You have used 3 of 3 submissions

PART I

(1/1 point)

What days are SP days under the optimal solution? Check all that apply

- [ ] Day 1
- [x] Day 2
- [ ] Day 3
- [x] Day 4

✔

You have used 1 of 3 submissions