For this assignment, you need to construct a personalized diet using current recommended dietary allowances from the U.S. Food and Drug Administration, updated to account for recent research on sodium intake and health (Mente, O'Donnell, and Yusuf 2021). Interested in learning more about nutrition and healthy living? Check out *Nutrients*, an open-access journal, at its home page https://www.mdpi.com/journal/nutrientsLinks to an external site. .

The constraints for this linear programming problem, should consider seven components of nutrition, as shown in the following table:

Component	*Max/Min*	*Amount and measure*
Sodium	Maximum	5,000 milligrams (mg)
Energy	Minimum	2,000 Calories (kilocalories, kcal)
Protein	Minimum	50 grams (g)
Vitamin D	Minimum	20 micrograms (mcg)
Calcium	Minimum	1,300 milligrams (mg)
Iron	Minimum	18 milligrams (mg)
Potassium	Minimum	4,700 milligrams (mg)

Set this up as a standard linear programming problem with decision variables taking any non-negative values. In other words, partial servings are permitted.

Nutrition labels on packaged foods should contain information about these eight components of nutrition along with other components. Each of the components represents a constraint in the linear programming problem you are developing.

To adapt the problem to your personal diet, collect nutrition facts from five packaged food items in your household. Use packaged foods that are part of your normal diet and for which you have prices. Also, ensure that the across the set of food items there are positive values for each of the eight components of nutrition. Adjust the price for each food item so that it represents one serving size, as defined on the nutrition facts label. Each food item represents a decision variable in the linear programming problem.

The goal or objective of this problem is to find the minimum-cost diet (servings of food items) that satisfies the eight nutritional requirements. Use Python Pulp to solve this linear programming problem.

Deliverables (150 points total, 30 points for each part)

Paper (pdf file). The paper/write-up should be submitted as a pdf file (2 pages max). Think of the paper as comprising the methods and results sections of a written research report. If you like, provide a paragraph on methods and a paragraph about results for each of the five parts of this assignment.

Program code (text link to GitHub repository). Key information from the paper should also be included in the README.md markdown file of a public GitHub repository established by the student. The GitHub repository should include text files for the program code (.py extension for Python), and program output (.txt extension). Include the web address (URL) of the GitHub repository text in the posted submission for the assignment. Image files (.jpg or .png extension) should be included for the scanned food labels.

Uploads are restricted to files with pdf, md, and txt extensions.

- **Part 1.** Provide documentation for the five packaged food items you have selected for the assignment. Photographs of the Nutrition Facts labels are sufficient. Show your price calculations for serving sizes.

Component	*Max/Min*	*Amount and measure*
Sodium	Maximum	5,000 milligrams (mg)
Energy	Minimum	2,000 Calories (kilocalories, kcal)
Protein	Minimum	50 grams (g)
Vitamin D	Minimum	20 micrograms (mcg)
Calcium	Minimum	1,300 milligrams (mg)
Iron	Minimum	18 milligrams (mg)

Potassium Minimum 4,700 milligrams (mg)

Nutrients	Energy	Sodium	Protein	Vit D	calcium	Iron	Potassium	Carb	Price
Sakara Bar	130 cal	130 mg	12g	0 mcg	38 mg	2 mg	144 mg	20 g	5$
Protein shake	290 cal	400 mg	35 g	2.6 mcg	300 mg	5.5 mg	318 mg	19 g	3.75$
Cookies	140 cal	85 mg	1 g	0 mcg	0 mg	1.25 mg	50 mg	19 g	1.75 $
Paneer	90 cal	5 mg	7 g	0 mcg	125 mg	0 mg	0 mg	0.5 g	2.00 $
Pasta	190 cal	0 mg	4 g	0 mcg	2 mg	0 mg	77 mg	44 g	1.25 $
Constraints	2000 cal	5000 (max) mg	50 gm	20 mcg	1300 mg	18 mg	4700 mg		

SAKARA BAR (FOOD item 1)

Lean Body Protein Shake

LEAN BODY®

Chocolate FLAVOR

35g PROTEIN

7g BCAAs & GLUTAMINE

7g DIETARY FIBER

GLUTEN FREE

Nutrition Facts

16 servings per container
Serving size **2 scoops (70g)**

Amount per serving
Calories **290**

	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 2g	**10%**
Trans Fat 0g	
Cholesterol 70mg	**23%**
Sodium 400mg	**15%**
Total Carbohydrate 19g	**7%**
Dietary Fiber 7g	**25%**
Total Sugars 3g	
Includes 0g Added Sugars	
Protein 35g	**70%**
Vitamin D 2.6mcg	15%
Calcium 300mg	25%
Iron 5.5mg	30%
Potassium 318mg	6%
Vitamin A 289mcg	30%
Vitamin C 16mg	20%
Vitamin E 6mg	40%
Thiamin 0.24mg	20%
Riboflavin 0.26mg	20%
Niacin 2.8mg	20%
Vitamin B_6 0.3mg	20%
Folate 70mcg DFE (41mcg Folic Acid)	20%
Vitamin B_{12} 0.42mcg	20%
Biotin 5mcg	15%
Pantothenic Acid 1mg	20%
Phosphorus 210mg	15%
Iodine 26mcg	15%
Magnesium 100mg	25%
Zinc 6mg	60%
Copper 0.2mg	20%
Chloride 30mg	2%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

NUTRITION FACTS MAY VARY BY FLAVOR.

INGREDIENTS:

Whey Protein Concentrate, Milk Protein Isolate, Sunflower Oil Creamer (High Oleic Sunflower Oil, Corn Starch, Sodium Caseinate (milk), Cocoa (processed with alkali), Natural Flavors, Polydextrose, Soluble Corn Fiber, Vitamin & Mineral Blend (Di-Calcium Phosphate, Magnesium Oxide, Ascorbic Acid, Vitamin E Acetate, Folic Acid, Biotin, Niacinamide, Potassium Iodide, Zinc Oxide, Electrolytic Iron, Vitamin A Acetate, Copper Gluconate, Calcium D-Pantothenate, Cyanocobalamin, Cholecalciferol, Pyridoxine Hydrochloride, Riboflavin, Thiamin Mononitrate), Cellulose Gum, Salt, Medium-Chain Triglycerides, Less than 2% of: Dipotassium Phosphate, Soy Lecithin, Silicon Dioxide, Natural Tocopherols, Acesulfame Potassium, Sucralose.

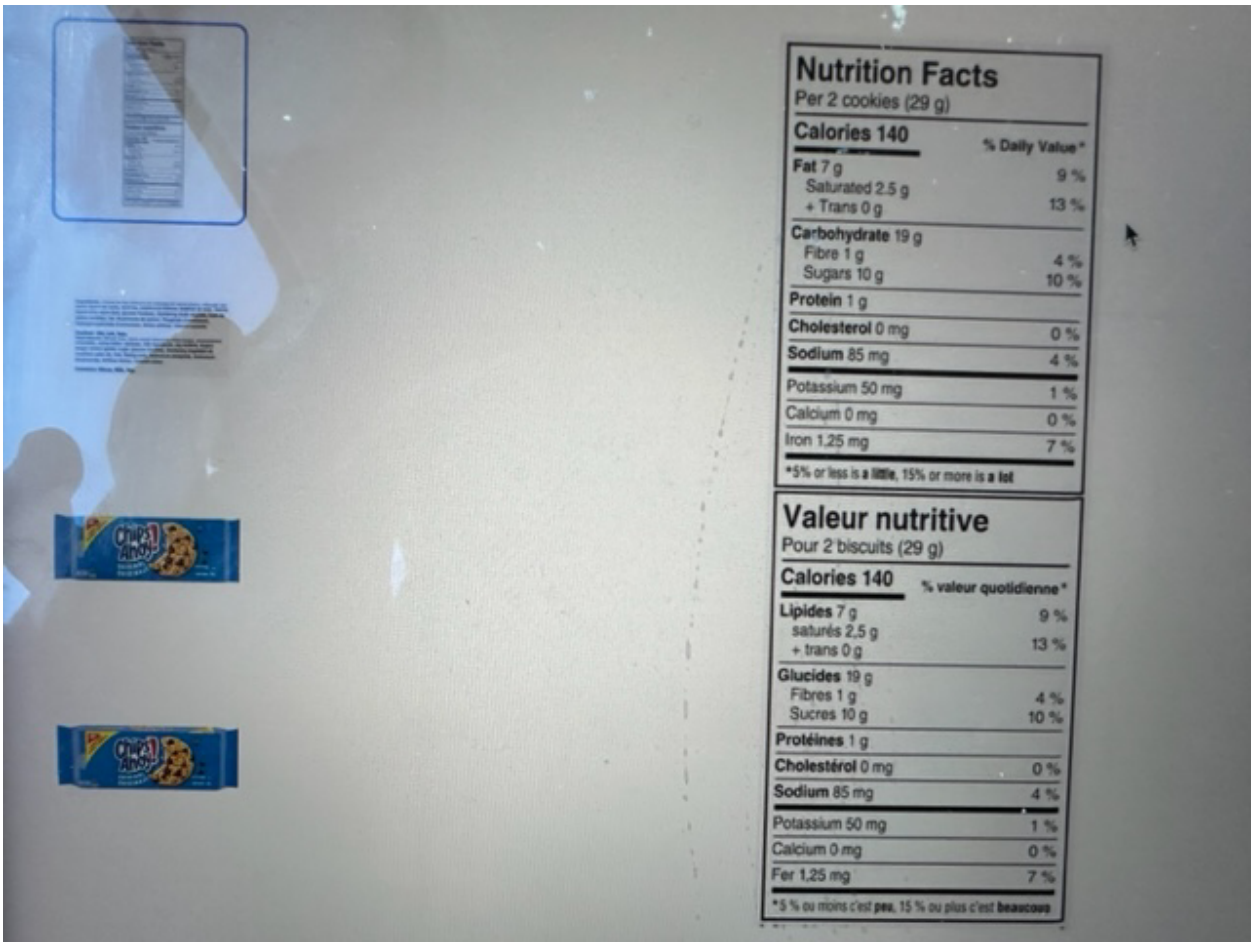
Contains: Milk, Soy (Lecithin).
Note: Soy lecithin helps the powder

METABOLISM PROTEIN SUPER BAR

NUTRITION FACTS PER SERVING

Amount per serving		% Daily Value
Calories	130	
Total Fat	7g	9%
Saturated Fat	2g	10%
Trans Fat	0g	
Cholesterol	0mg	0%
Sodium	130mg	6%
Total Carbohydrate	20g	7%
Dietary Fiber	11g	39%
Total Sugars	3g	
Includes 0g Added Sugars		0%
Protein	12g	
Vitamin D	0mcg	0%
Calcium	38mg	2%
Iron	2mg	10%
Potassium	144mg	4%

ALL INGREDIENTS


Nutrition Facts
Per 2 cookies (29 g)
Calories 140
% Daily Value*
Fat 7 g
9 %
Saturated 2.5 g
+ Trans 0 g
13 %
Carbohydrate 19 g
Fibre 1 g
4 %
Sugars 10 g
10 %
Protein 1 g
Cholesterol 0 mg
0 %
Sodium 85 mg
4 %
Potassium 50 mg
1 %
Calcium 0 mg
0 %
Iron 1.25 mg
7 %
*5% or less is a little, 15% or more is a lot
Valeur nutritive
Pour 2 biscuits (29 g)
Calories 140
% valeur quotidienne*
Lipides 7 g
9 %
saturés 2,5 g
+ trans 0 g
13 %
Glucides 19 g
Fibres 1 g
4 %
Sucres 10 g
10 %
Protéines 1 g
Cholestérol 0 mg
0 %
Sodium 85 mg
4 %
Potassium 50 mg
1 %
Calcium 0 mg
0 %
Fer 1,25 mg
7 %
*5 % ou moins c'est peu, 15 % ou plus c'est beaucoup

NUTRITION FACTS

6 Servings per container

Serving size **2 oz** (56 g)

	Per Serving	
Calories	**190**	
		%DV*
Total Fat	1g	**1%**
Saturated Fat	0g	**0%**
Trans Fat	0g	
Cholesterol	0mg	**0%**
Sodium	0mg	**0%**
Total Carb.	44g	**16%**
Dietary Fiber	2g	**7%**
Soluble Fiber	1g	
Insoluble Fiber	1g	
Total Sugars	0g	
Protein	4g	
Vitamin D	0mcg	0%
Calcium	2mg	0%
Iron	0mg	0%
Potassium	77mg	2%

Not a significant source of added sugars.

INGREDIENTS:

CORN FLOUR, RICE FLOUR
MONO AND DIGLYCERIDES

NO WHEAT INGREDIENTS, PRODUCED ON A DEDICATED GLUTEN FREE LINE

CERTIFIED GLUTEN

NON GMO


NO PRESERVATIVES • NO STARCH • NO GUMS
ਪਨੀਰ
पनीर
MADE WITH MILK FROM COWS NOT TREATED WITH rbST GUARANTEE
GOPI
REAL CALIFORNIA MILK
LOW SODIUM
Paneer
FRESH CHEESE
HALAL
Nutrition Facts
8 Servings per Container
Serving size 1 oz (28g)
Calories per serving 90
Amount/Serving % DV
Total Fat 7g 9%
Sat. Fat 5g 25%
Trans Fat 0g
Cholest. 25mg 8%
Sodium 5mg 0%
Amount/Serving % DV
Total Carb. <1g 0%
Dietary Fiber 0g 0%
Total Sugars 1g
Includes 0g Added Sugars 0%
Protein 7g
Vitamin D 0% • Calcium 8% • Iron 0% • Potassium 0%
**Made with milk from cows not treated with the growth hormone rbST. No significant difference has been shown between milk derived from rbST-treated and non-rbST-treated cows.
Ingredients: Pasteurized Grade A Milk and Vinegar.
Keep Refrigerated
Use Within 5 Days of Opening Package
NET WT. 8 OZ (226G)
Dist. by Karoun Dairies, LLC, San Fernando, CA 91340 - (888) 767 0778 - karouncheese.com
BEST IF USED BY: 09/16/22
VAT # 11 L2 7 20:06 140c

- **Part 2.** Specify the linear programming problem in standard form, showing decision variables, objective function with cost coefficients, and nutritional constraints. Describe the problem in plain English.

  Here's the linear programming problem in standard form for the diet optimization problem you provided:

  Decision Variables:

  - bar: The number of servings of the "bar" food item.

  - shake: The number of servings of the "shake" food item.

  - paneer: The number of servings of the "paneer" food item.

  - cookies: The number of servings of the "cookies" food item.

  - past`: The number of servings of the "pasta" food item.

  Objective Function:

  Minimize: 5*(bar)+ 3.75 * (shake) + 1.75*(paneer) + 2*(cookies) + 1.25*(pasta)

  Nutritional Constraints:

  1. Energy Constraint: 130*(bar) + 290*(shake) + 140*(cookies) + 90*(paneer) + 190*(pasta)>= 2000 (Energy should be at least 2000 Calories).

  2. Sodium Constraint: 130*(bar) + 400*(shake) + 85*(cookies) + 5*(paneer) <=5000 (Sodium should not exceed 5000 milligrams).

  3. Protein Constraint: 12*(bar) + 35*(shake)+ 1*(cookies) + 7*(paneer) + 4* (pasta) >=800 (Protein should be at least 800 grams).

  4. Vitamin D Constraint: 2.6*(shake) >= 20 (Vitamin D should be at least 20 micrograms).

  5. Calcium Constraint: 38* (bar) + 300 * (shake) + 125* (paneer) + 2* (pasta) >= 1300 (Calcium should be at least 1300 milligrams).

6. Iron Constraint: 2* (bar) + 5.5 * (shake)+ 1.25 * (cookies)>= 18 (Iron should be at least 18 milligrams).

7. Potassium Constraint: 144*(bar) + 318*(shake) + 50 *(cookies) + 77 *(pasta)>= 4700 (Potassium should be at least 4700 milligrams).

Plain English Description:

The goal of this linear programming problem is to find the most cost-effective diet plan while ensuring that the diet meets specific nutritional requirements. We have five food items, each with a cost per serving. The objective is to minimize the cost of the diet, which is calculated by multiplying the servings of each food item by its respective cost.

There are constraints that the diet must satisfy:

- The total energy (calories) in the diet should be at least 2000 calories.

- The diet should not exceed 5000 milligrams of sodium.

- The diet should contain at least 800 grams of protein.

- There should be at least 20 micrograms of vitamin D in the diet.

- The diet should provide at least 1300 milligrams of calcium.

- A minimum of 18 milligrams of iron should be in the diet.

- The diet should contain at least 4700 milligrams of potassium.

The decision variables represent the servings of each food item, and the objective is to find the optimal combination of servings to meet these constraints while minimizing the cost.

- **Part 3.** Implement the linear programming problem using Python PuLP. Provide the program code and output/listing as plain text files (.py, .txt). (If you use Jupyter notebook, export the code as a plain Python text file and save the code and listing as an HTML file.)
-
- **Part 4.** Describe the solution for the linear programming problem, showing units (serving sizes) for each of the five food items. What is the minimum cost solution? How much would you need to spend on food each day?

- Optimal diet:
- Servings of Bar: 0.0
- Servings of Shake: 11.900137

- Servings of Paneer: 47.989064
- Servings of Cookies: 0.0
- Servings of Pasta: 11.892942
- Total cost: $143.47255325

  Here's what the results indicate:

  - I should have 0 servings of "Bar."
  - I should have approximately 11.9 servings of "Shake."
  - I should have nearly 48 servings of "Paneer."
  - I should have 0 servings of "Cookies."
  - I should have around 11.89 servings of "Pasta."

  This combination of servings meets the nutritional constraints and minimizes the cost. The total cost of this diet plan is approximately $143.47.

  This means that, according to the optimization, the most cost-effective and healthy diet would consist mainly of "Shake," "Paneer," and "Pasta," with no "Bar" or "Cookies."

  This seems rather impractical and could be related to the nutritional constraints od Vit D, Iron etc which are lacking in items chosen at home.

- **Part 5.** What happens when you add additional nutritional constraints, drawing from recommendations of the U.S. Food and Drug Administration: https://www.fda.gov/media/99069/downloadLinks to an external site.. Try adding two to six nutritional constraints, such as minimum requirements for vitamin C, niacin (vitamin B3), vitamin E, vitamin B6, and magnesium, for example. Solve the revised linear programming problem. How does this change the solution? Did you have to add food items to satisfy the expanded set of constraints? How much more would you have to spend on food each day?

I will add two nutritional constraints such as minimum requirements for Vit C and Vit B6. Minimal requirements and nutritional constraints for Vit C are 90 milligrams and Vit B6 is 1.7 milligrams.

Optimal diet:
Servings of Bar: 0.0
Servings of Shake: 11.900137
Servings of Paneer: 47.989064
Servings of Cookies: 0.0
Servings of Pasta: 11.892942

Total cost: $143.47255325

Serving size and cost of the optimal diet does not change since Shake that is the only foot item carrying vit C and B6 is in high serving quantities. And it is in ample amounts in the optimal solution of the diet.

Github URL: https://github.com/masoom7d/MSDS-460.git