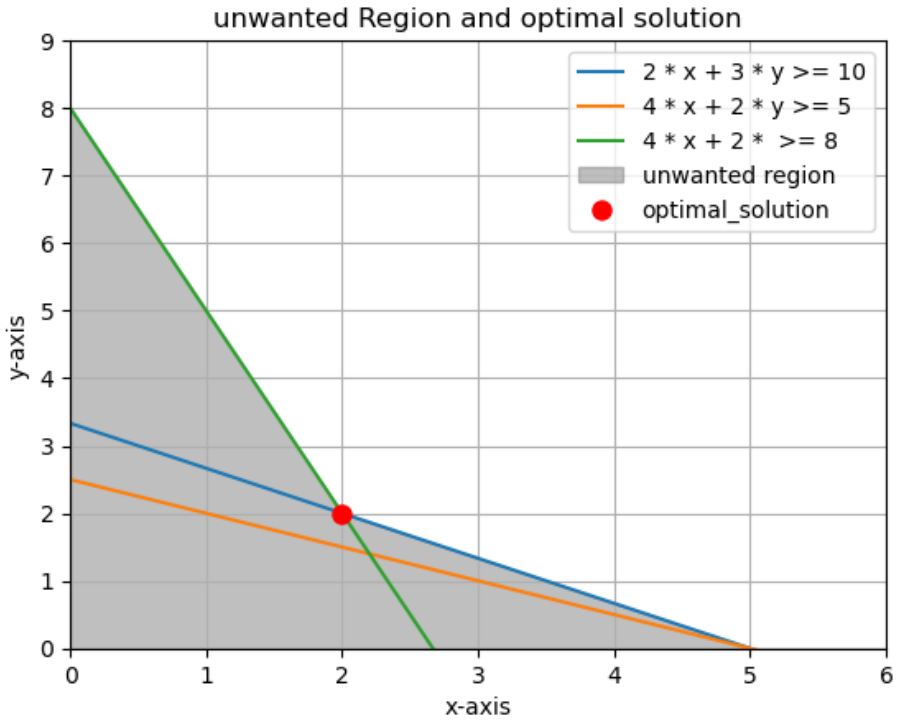
February 16, 2024

MOUNTAINS OF THE MOON UNIVERSITY
FACULTY OF SCIENCE, TECHNOLOGY AND INNOVATION
DEPARTMENT OF COMPUTER SCIENCE
YEAR ONE
SEMESTER TWO
COURSE NAME: LINEAR PROGRAMMING
COURSE CODE: BCS 1201
LECTURERS NAME: SAMUEL OCEN
INDIVIDUAL COURSE WORK
NAME: TUGUME JAMES
REG NO: 2023/U/MMU/BCS/0I680

```
NO 1 BASIC RESOURCE ALLOCATION
from pulp import LpProblem, LpVariable, LpMinimize


model = LpProblem(name="Minimize_cost_of_Resource_Allocation", sense=LpMinimize)

# definiing the objective variables of linear programming problem
x = LpVariable(name=("x"), lowBound=0)
y = LpVariable(name=("y"), lowBound=0)

#defining the objective function of the linear programming problem
model += 4 * x + 5 * y


model += 2 * x + 3 * y >= 10 # CPU
model += x + 2 * y >= 5 # memory
model += 3 * x + y >= 8 # storage

#solve the proble
```

```
model.solve()

#display the result
print("Optimal value:")
print(f"optimal value (x): {x.varValue}")
print(f"optimal value (y): {y.varValue}")
print(f"minimum_cost (Z): {model.objective.value()}")
Optimal value:
optimal value (x): 2.0
optimal value (y): 2.0
minimum_cost (Z): 18.0

#graph for no1 resource allocation*

import numpy as np
import matplotlib.pyplot as plt
#converting constraints to inqualities
x = np.linspace(0,6,400)
#convert constraints into inqualities
y1 = (10 - 2 * x)/3
y2 = (5 - x)/2
y3 = (8 - 3 * x)

#plot constraints

plt.plot(x, y1, label = "2 * x + 3 * y >= 10") #CPU

plt.plot(x, y2, label = "4 * x + 2 * y >= 5") #Memory

plt.plot(x, y3, label = "4 * x + 2 *  >= 8") #storage

#defining the unwanted region
y4 = np.maximum.reduce([y1, y2 ,y3])

plt.fill_between(x, y4, 0, color = "gray", alpha = 0.5, label="unwanted region")

#plot the optimal solution point
optimal_x=2.0
optimal_y=2.0
plt.plot(2, 2, "ro", markersize=8, label="optimal_solution")
plt.xlim(0, 6)
plt.ylim(0, 9)
plt.grid(True)
plt.legend()
plt.xlabel("x-axis")
plt.ylabel("y-axis")
```

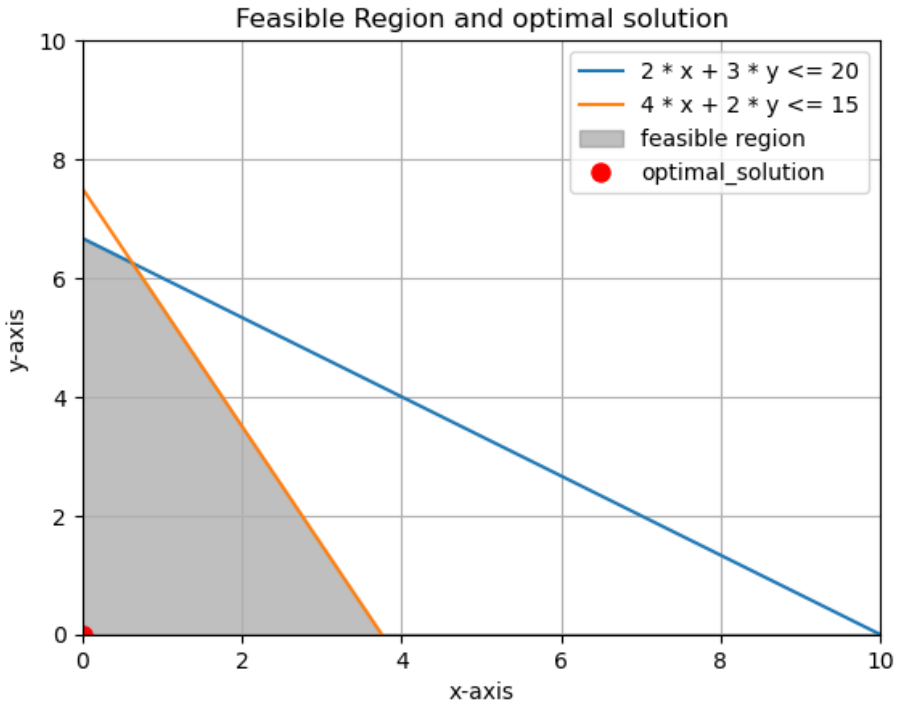
```
plt.title("unwanted Region and optimal solution")
```



NO2 LOAD BALANCING

```
  #importing necessary libraries

from pulp import LpProblem, LpVariable, LpMinimize

# creating a linear programming minimization problem

model = LpProblem(name="minimize_the_overall_response_time", sense=LpMinimize)

# definiing the objective variables of linear programming problem

x = LpVariable(name=("x"), lowBound=0)
y = LpVariable(name=("y"), lowBound=0)

#defining the objective function of the linear programming problem

model += 5 * x + 4 * y

#defining the constraints of the linear programing problem

model += 2 * x + 3 * y <= 20 #server 1 capacity
model += 4 * x + 2 * y <= 15 # server2 capcity

#solve the problem
model.solve()

#display the result
print("Optimal value:")
print(f"optimal value (x): {x.varValue}")
print(f"optimal value (y): {x.varValue}")
print(f"minimum_overall_time (Z): {model.objective.value()}")

Optimal value:
optimal value (x): 0.0
optimal value (y): 0.0
minimum_overall_time (Z): 0.0

code for graph of loading balancing

  import numpy as np
import matplotlib.pyplot as plt
#converting constraints to inqualities
x = np.linspace(0,15,400)

y1 = (20 - 2* x)/3
```

```
y2 = (15 - 4 * x)/2
#plot constraints
plt.plot(x, y1, label = "2 * x + 3 * y <= 20")
plt.plot(x, y2, label = "4 * x + 2 * y <= 15" )

#define the feasible region
y3 = np.minimum(y1, y2)

plt.fill_between(x, y3, color = "gray", alpha = 0.5, label="feasible region")

#plot the optimal solution point
optimal_x=0
optimal_y=0
plt.plot(0, 0, "ro", markersize=8, label="optimal_solution")
#define the limits
plt.xlim(0, 10)
plt.ylim(0, 10)
plt.grid(True)
plt.legend()
plt.xlabel("x-axis")
plt.ylabel("y-axis")
plt.title("Feasible Region and optimal solution")
```

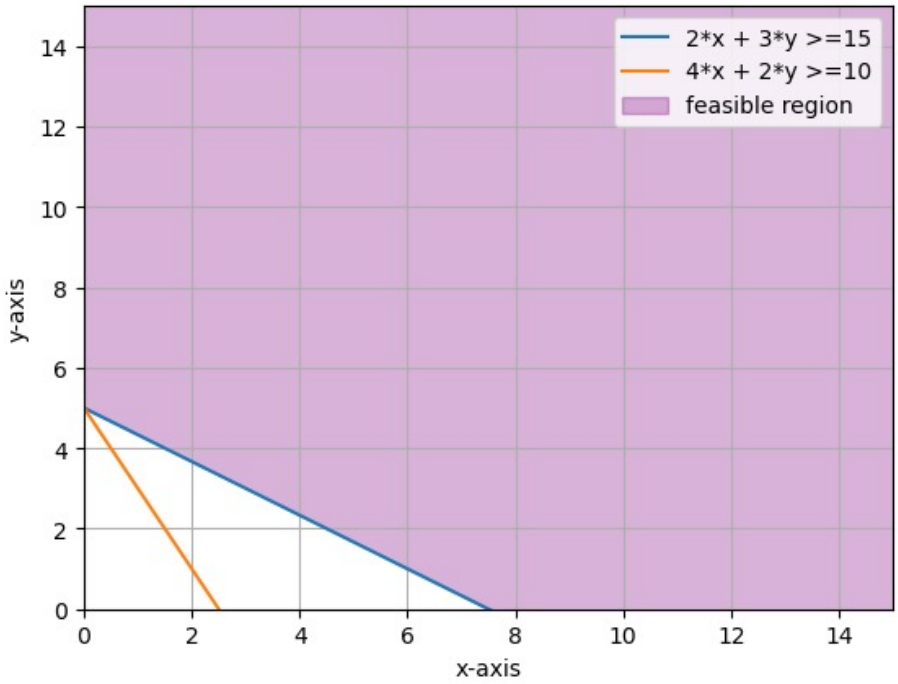

Feasible Region and optimal solution
2 * x + 3 * y <= 20
4 * x + 2 * y <= 15
feasible region
optimal_solution
y-axis
x-axis
0
2
4
6
8
10

```
N0.3 ENERGY EFFICIENT RESOURCE ALLOCATION
1
from pulp import LpProblem,LpMinimize,LpVariable
import matplotlib.pyplot as plt
import numpy as np
#LpProblem
model = LpProblem(name="Energy-Efficient_resource_allocation",sense=LpMinimize)
#variables
x=LpVariable("x",0)
y=LpVariable("y",0)
#objective function
model+= 3*x + 2*y
#Constraints
model+= 2*x + 3*y >= 15,"CPU Allocation Constraint"
model+= 4*x + 2*y >= 10," Memory Allocation Constraint"
#Solving
model.solve()
#resluts
optimal_x=x.varValue
optimal_y=y.varValue
optimal_value = model.objective.value()
print("optimal solution:")
print("x:",optimal_x)
print("y:",optimal_y)
print("z:",optimal_value)
optimal solution:
x: 0.0
y: 5.0
z: 10.0
\[CODES FOR GRAPH\]
import matplotlib.pyplot as plt
import numpy as np
#define x array
x=np.linspace(0,17,15000)
#convert constraints to inequalities
y1=(15-2*x)/3
```

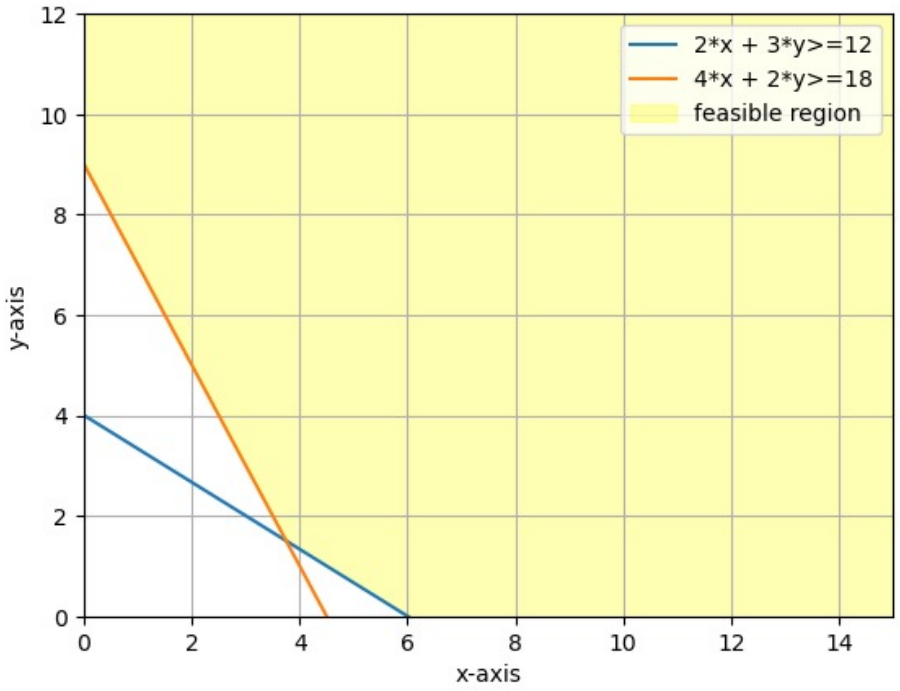
```
y2=(10-4*x)/2
#plot constraints
plt.plot(x,y1,label="2*x + 3*y >=15")
plt.plot(x,y2,label="4*x + 2*y >=10")
#define the feasible region
y3 =np.maximum.reduce([y1,y2])
plt.fill_between(x,y3,15,color="purple",label="feasible region",alpha=0.3)
# define limits
plt.xlim(0,15)
plt.ylim(0,15)
2
ENERGY EFFICIENT RESOURCE ALLOCATION.png
Figure 1: graph for number three
plt.grid(True)
plt.xlabel ("x-axis")
plt.ylabel("y-axis")
plt.legend()
plt.show()
3
NO 4.MULTI-TENANT RESOURCE SHARING
from pulp import LpProblem,LpMinimize,LpVariable
import matplotlib.pyplot as plt
import numpy as np
#LpProblem
model = LpProblem(name="Multi_Tenant_Resource_Sharing",sense=LpMinimize)
#variables
x=LpVariable("x",0)
y=LpVariable("y",0)
#objective function
model+= 5*x + 4*y
#Constraints
model+= 2*x + 3*y >= 12,"Tenant 1 Constraint"
model+= 4*x + 2*y >= 18,"Tenant 2 Constraint"
#Solving
model.solve()
#resluts
optimal_x=x.varValue
optimal_y=y.varValue
optimal_value = model.objective.value()
print("optimal solution:")
print("x:",optimal_x)
print("y:",optimal_y)
print("z:",optimal_value)
optimal solution:
x: 3.75
y: 1.5
```

```
z: 24.75
\[CODES FOR GRAPH\]
import matplotlib.pyplot as plt
import numpy as np
#define the x array
x= np.linspace(0,15,20000)
#convert constraints to inequalities
y1=(12-2*x)/3
y2=(18-4*x)/2
#=plot constraints
plt.plot(x,y1,label="2*x + 3*y>=12")
plt.plot(x,y2,label="4*x + 2*y>=18")
#define the feasible region
y3 =np.maximum.reduce([y1,y2])
plt.fill_between(x,y3,13,color="yellow",label="feasible region",alpha=0.3)
#define limits
plt.xlim(0,15)
4
MULTI-TENANT RESOURCE SHARING.png
Figure 2: Graph for number four
plt.ylim(0,12)
plt.grid(True)
plt.xlabel ("x-axis")
plt.ylabel ("y-axis")
plt.legend()
plt.show()
5
\begin{verbatim}
N0.3 ENERGY EFFICIENT RESOURCE ALLOCATION
from pulp import LpProblem,LpMinimize,LpVariable
import matplotlib.pyplot as plt
import numpy as np
#LpProblem
model = LpProblem(name="Energy-Efficient_resource_allocation",sense=LpMinimize)
#variables
x=LpVariable("x",0)
y=LpVariable("y",0)
#objective function
model+= 3*x + 2*y
#Constraints
model+= 2*x + 3*y >= 15,"CPU Allocation Constraint"
model+= 4*x + 2*y >= 10," Memory Allocation Constraint"
#Solving
model.solve()
#resluts
optimal_x=x.varValue
```

```
optimal_y=y.varValue
optimal_value = model.objective.value()
print("optimal solution:")
print("x:",optimal_x)
print("y:",optimal_y)
print("z:",optimal_value)
optimal solution:
x: 0.0
y: 5.0
z: 10.0
\[CODES FOR GRAPH\]
import matplotlib.pyplot as plt
import numpy as np
#define x array
x=np.linspace(0,17,15000)
#convert constraints to inequalities
y1=(15-2*x)/3
y2=(10-4*x)/2
#plot constraints
plt.plot(x,y1,label="2*x + 3*y >=15")
plt.plot(x,y2,label="4*x + 2*y >=10")
#define the feasible region
y3 =np.maximum.reduce([y1,y2])
plt.fill_between(x,y3,15,color="purple",label="feasible region",alpha=0.3)
# define limits
6
ENERGY EFFICIENT RESOURCE ALLOCATION.png
Figure 3: graph for number three
plt.xlim(0,15)
plt.ylim(0,15)
plt.grid(True)
plt.xlabel ("x-axis")
plt.ylabel("y-axis")
plt.legend()
plt.show()
```


2*x + 3*y >=15
4*x + 2*y >=10
feasible region
y-axis
x-axis
0
2
4
6
8
10
12
14

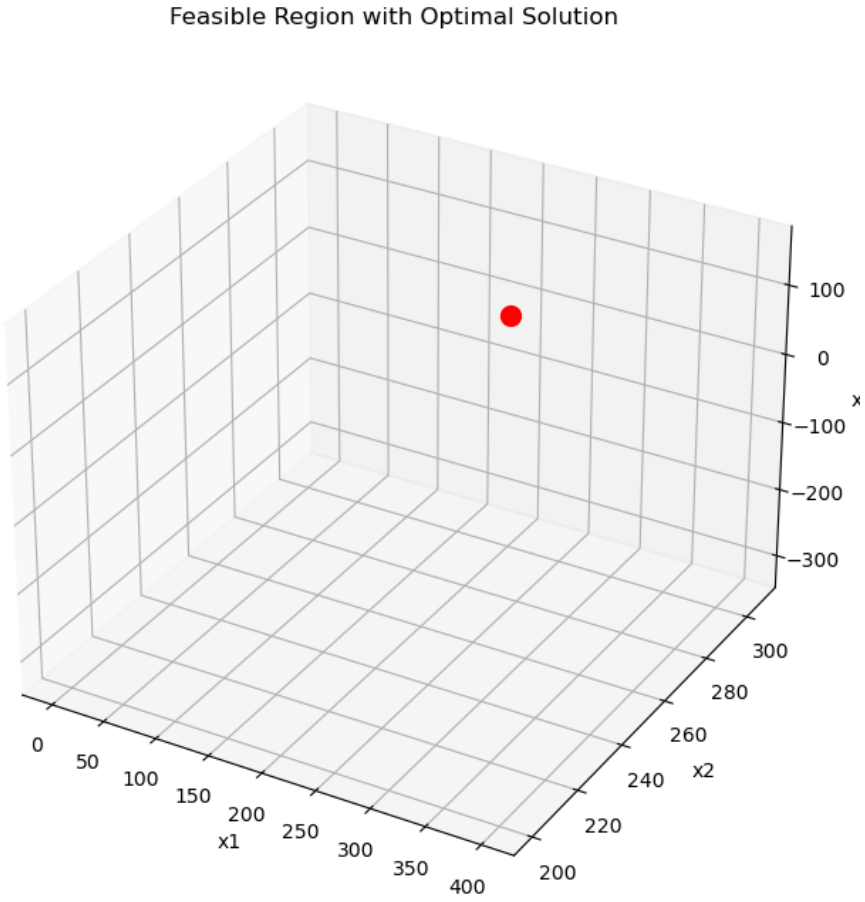
N0 4.MULTI-TENANT RESOURCE SHARING from pulp import LpProblem,LpMinimize,LpVariable import matplotlib.pyplot as plt import numpy as np LpProblem model = LpProblem(name="Multi$_T$enant$_R$esource$_S$haring", $sense = LpMinimize)variablesx = LpVariable("x", 0)y = LpVariable("y", 0)objectivefunctionmodel+ = 5*x+4*yConstraintsmodel+ = 2*x+3*y >= 12, "Tenant1Constraint"model+ = 4*x+2*y >= 18, "Tenant2Constraint"Solvingmodel.solve()reslutsoptimal_x = x.varValueoptimal_y = y.varValueoptimal_value = model.objective.value()print("optimalsolution : ")print("x : ", optimal_x)print("y : ", optimal_y)print("z : ", optimal_value)optimalsolution : x : 3.75y : 1.5z : 24.75CODESFORGRAPHimportmatplotlib.pyplotaspltimportnumpyasnpdefinethexarray np.linspace(0, 15, 20000)convertconstraintstoinequalitiesy1 = (12−2*x)/3y2 = (18−4*x)/2 = plotconstraintsplt.plot(x, y1, label = "2*x+3*y >= 12")plt.plot(x, y2, label = "4*x+2*y >= 18")definethefeasibleregiony3 = np.maximum.reduce([y1, y2])plt.fill_between(x, y3, 13, color "yellow", label = "feasibleregion", alpha = 0.3)definelimitsplt.xlim(0, 15)8MULTI−TENANTRESOURCESHARING.pngFigure4 : Graphfornumberfourplt.ylim(0, 12)plt.grid(True)plt.xlaaxis")plt.ylabel("y − axis")plt.legend()plt.show()9



```
NO 5 PRODUCTION PLANNING MANUFACTURING

from pulp import LpProblem, LpVariable, LpMinimize


model = LpProblem(name="Minimizing_the_production_cost", sense=LpMinimize)

# definiing the objective variables

x1 = LpVariable(name=("x1"), lowBound=0)
x2 = LpVariable(name=("x2"), lowBound=0)
x3 = LpVariable(name=("x3"), lowBound=0)

#defining the objective function
model += 5 * x1 + 3 * x2 + 4 * x3

#defining the constraints

model += 2 * x1 +3 * x2 + x3 <= 1000    #available raw material

model += 4 * x1 + 2 * x2 + 5 * x3 <= 120 # Available hours

model += x1 >= 200 #demand constraint , minimum product constrains

model += x2 >= 300 #demand constraint , minimum product constrains

model += x3 >= 150 #demand constraint , minimum product constrains

#solve the proble

model.solve()

#display the result
print("Optimal value:")
print(f"Quantity of product (x1): {x1.varValue}")
print(f"Quantity of product (x2): {x2.varValue}")
print(f"Quantity of product (x2): {x3.varValue}")
print(f"minimum value(Z): {model.objective.value()}")

Optimal value:
Quantity of product (x1): 200.0
Quantity of product (x2): 300.0
Quantity of product (x2): 0.0
minimum value(Z): 1900.0

codes for production planning no 5
```

```
# importing necessary libraries

import numpy as np
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D

# coverting  the constraints into inequalities

def constraint1(x1):
    return (1000 - 2 * x1) / 3

def constraint2(x1):
    return (25 - 4 * x1) / 5

def constraint3(x1):
    return 300

def constraint4(x1):
    return 150

# Create arrays of x1 values for plotting

x1_values = np.linspace(0, 400, 100)

# Calculate corresponding x2 and x3 values based on the constraints

x2_values = constraint1(x1_values)
x3_values = constraint2(x1_values)


fig = plt.figure(figsize=(10, 8))
ax = fig.add_subplot(111, projection='3d')

# Plot the feasible region surface

ax.plot_surface(x1_values.reshape(-1, 1), np.full_like(x1_values, 300), x3_values.reshape(-1

# Define the unwanted region

x1_unwanted = np.linspace(200, 40, 100)
x3_unwanted = np.full_like(x1_unwanted, 150)
x2_unwanted = constraint1(x1_unwanted)

# Plot the unwanted region surface
```

```
ax.plot_surface(x1_unwanted.reshape(-1, 1), x2_unwanted.reshape(-1, 1), x3_unwanted.reshape(

optimal_x1 = 200.0
optimal_x2 = 300.0
optimal_x3 = 0.0
ax.scatter(optimal_x1, optimal_x2, optimal_x3, color='red', s=100, label='Optimal Solution')

ax.set_xlabel('x1')
ax.set_ylabel('x2')
ax.set_zlabel('x3')
ax.set_title('Feasible Region with Optimal Solution')
plt.show()
```



```
    NO 6 FINANCIAL PORTFOLIO OPTIMIZATION

    #importing necessary libraries
from pulp import LpProblem, LpVariable, LpMaximize
# creating a linear programming minimization problem
model = LpProblem(name="Maximize_the_return_on_investment", sense=LpMaximize)

# definiing the objective variables

x1 = LpVariable(name=("x1"), lowBound=0)   #investment in stock A
x2 = LpVariable(name=("x2"), lowBound=0)   #investment in stock B
x3 = LpVariable(name=("x3"), lowBound=0)   #investment in stock C

#defining the objective function

model += 0.08 * x1 + 0.1 * x2 + 0.12 * x3

#defining the constraints

model += 2 * x1 + 3 * x2 + x3 <= 10000  # bubget constraint (maximum Budget for investment)
model += x1 >= 2000                      # minimum investment constraints
model += x2 >= 1500                      # minimum investment constraints
model += x3 >= 1000                      # minimum investment constraints

#solve the problem

model.solve()

#display the result

print("Optimal value:")
print(f"optimal value (x1): {x1.varValue}")
print(f"optimal value (x2): {x2.varValue}")
print(f"optimal value (x3): {x3.varValue}")
print(f"maximum_return_on_investment (Z): {model.objective.value()}")

Optimal value:
optimal value (x1): 2000.0
optimal value (x2): 1500.0
optimal value (x3): 1500.0
maximum_return_on_investment (Z): 490.0

codes for  no 6 in 3D

import numpy as np
import matplotlib.pyplot as plt
```

```
from mpl_toolkits.mplot3d import Axes3D

# Define the constraints
def constraint1(x1):
    return (10000 - 2 * x1) / 3

def constraint2(x1):
    return (10000 - 2 * x1) / 3

def constraint3(x1):
    return (10000 - 2 * x1) / 3

# Create arrays of x1 values for plotting
x1_values = np.linspace(0, 5000, 1000)

# Calculate corresponding x2 and x3 values based on the constraints
x2_values = constraint1(x1_values)
x3_values = constraint2(x1_values)

# Plot the constraints
fig = plt.figure(figsize=(10, 8))
ax = fig.add_subplot(111, projection='3d')
ax.plot(x1_values, x2_values, x3_values, color='b', alpha=0.3)

# Plot the feasible region surface
X1, X3 = np.meshgrid(x1_values, x3_values)
X2 = constraint1(x1_values)
ax.plot_surface(X1, X2, X3, color='gray', alpha=0.5, label='Feasible Region')

# Plot the optimal solution point

optimal_x1 = 2000  # Optimal value for x1
optimal_x2 = 1500  # Optimal value for x2
optimal_x3 = 1500  # Optimal value for x3
ax.scatter(optimal_x1, optimal_x2, optimal_x3, color='red', s=100, label='Optimal Solution')

# Plot the point of intersection

ax.scatter(2000, 1500, 1500, color='red', s=100, label='Point of Intersection (2000, 1500, 1

ax.set_xlabel('x1')
ax.set_ylabel('x2')
ax.set_zlabel('x3')
ax.set_title('Feasible Region with Optimal Solution')
plt.show()
```

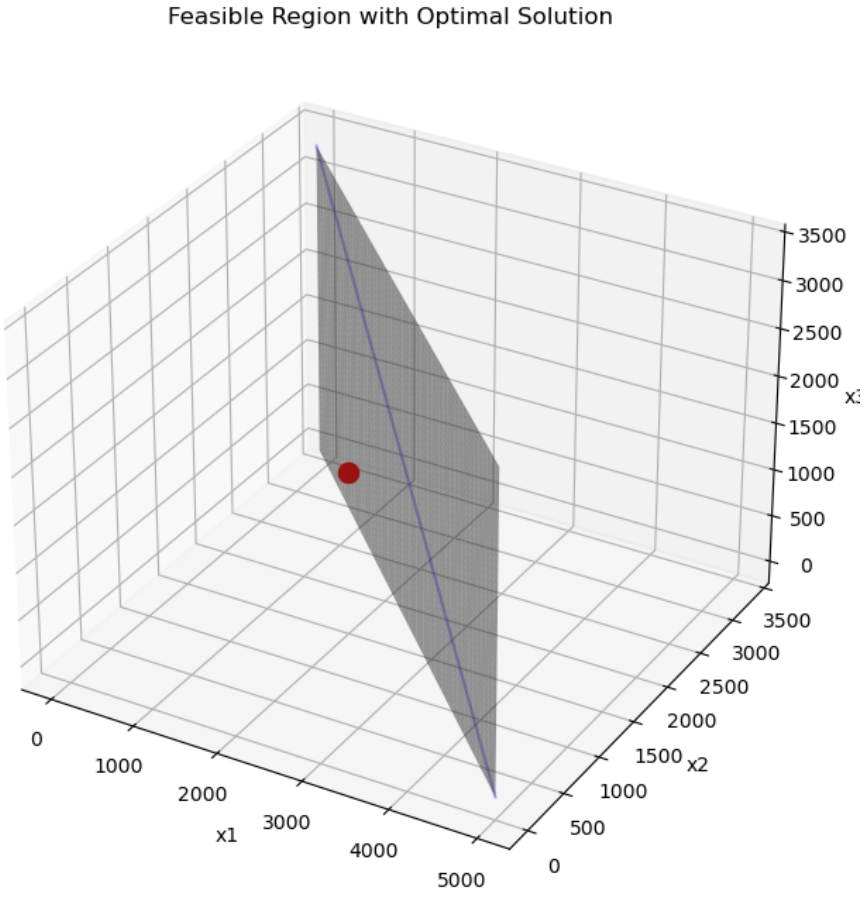
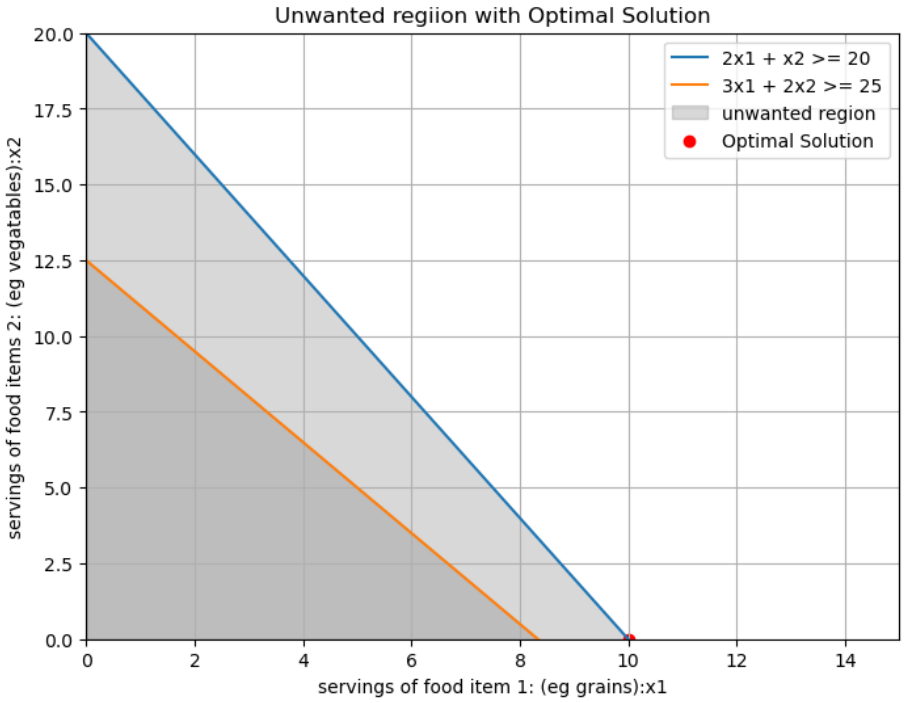


Figure 1: graph for portfolio optimization no 6 feasible region

```
    NO 7 DIET OPTIMIZATION

    from pulp import LpProblem, LpVariable, LpMinimize#my codes

# creating a linear programming minimization problem

model = LpProblem(name="Minimizing_the_cost_of_daily", sense=LpMinimize)

# definiing the objective variableS

x1 = LpVariable(name=("x1"), lowBound=0)

x2 = LpVariable(name=("x2"), lowBound=0)

#defining the objective function

model += 3 * x1 + 2 * x2

#defining the constraints of the linear programing problem

model += 2 * x1 + x2 >= 20  #proteins in grams

model += 3 * x1 + 2 * x2 >= 25 # vitamin in units

#solve the problem

model.solve()

#display the result

print("Optimal value:")
print(f"Quantity of product (x1): {x1.varValue}")
print(f"Quantity of product (x2): {x2.varValue}")
print(f"minimum value(Z): {model.objective.value()}")

Optimal value:
Quantity of product (x1): 10.0
Quantity of product (x2): 0.0
minimum value(Z): 30.0

codes for graph of no 7 unwanted region

from pulp import LpProblem, LpVariable, LpMinimize
import numpy as np
import matplotlib.pyplot as plt
```

```
# creating a linear programming minimization problem

model = LpProblem(name="Minimizing_the_cost_of_daily", sense=LpMinimize)

# defining the objective variables

x1 = LpVariable(name="x1", lowBound=0)
x2 = LpVariable(name="x2", lowBound=0)

# defining the objective function
model += 3 * x1 + 2 * x2

# defining the constraints of the linear programming problem

model += 2 * x1 + x2 >= 20      # proteins in grams
model += 3 * x1 + 2 * x2 >= 25  # vitamin in units

# solve the problem

model.solve()

# display the result

print("Optimal value:")
print(f"Quantity of product (x1): {x1.varValue}")
print(f"Quantity of product (x2): {x2.varValue}")
print(f"Minimum value(Z): {model.objective.value()}")

# Create a grid of points

x1_values = np.linspace(0, 15, 400)
x2_values = np.linspace(0, 15, 400)

#X1, X2 = np.meshgrid(x1_values, x2_values)

# Plot the constraints

plt.figure(figsize=(8, 6))
plt.plot(x1_values, 20 - 2*x1_values, label="2x1 + x2 >= 20")
plt.plot(x1_values, (25 - 3*x1_values)/2, label="3x1 + 2x2 >= 25")

# Shade the unwanted region

plt.fill_between(x1_values, 0,(20 - 2*x1_values),where=((20-2*x1_values) >= 0),color='gray'
plt.fill_between(x1_values, 0,(25 - 3*x1_values)/2, where=((25 - 3*x1_values)/2 >= 0),color=
```

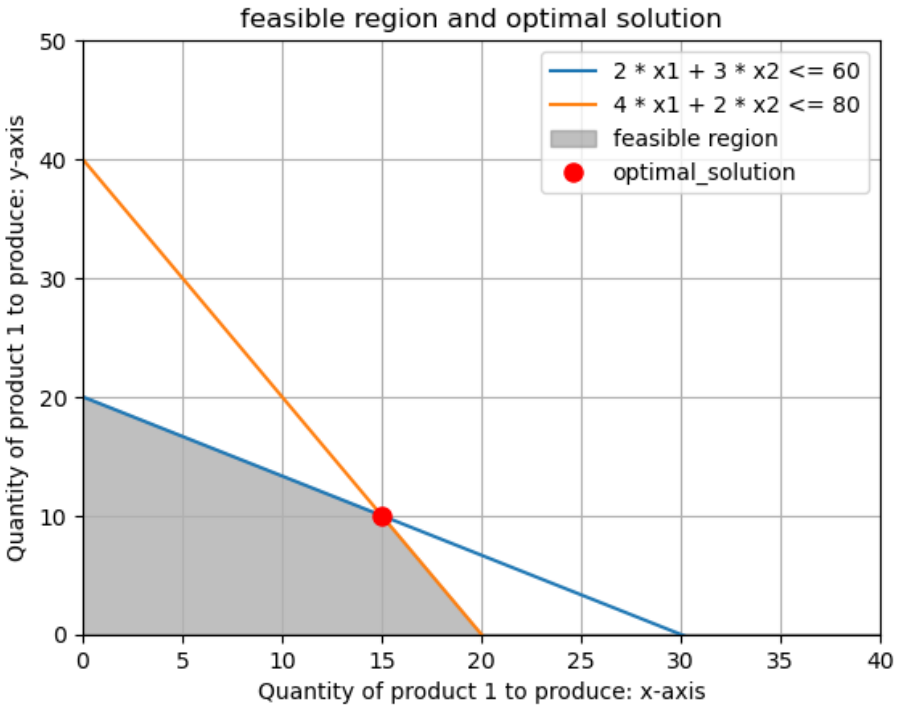
```
# Plot the optimal solution point

plt.scatter(x1.varValue, x2.varValue, color='red', label="Optimal Solution")

plt.xlabel("servings of food item 1: (eg grains):x1")
plt.ylabel("servings of food items 2: (eg vegatables):x2")
plt.title("Unwanted regiion with Optimal Solution")
plt.legend()
plt.grid(True)
plt.xlim(0, 15)
plt.ylim(0, 20)
plt.show()

Optimal value:
Quantity of product (x1): 10.0
Quantity of product (x2): 0.0
Minimum value(Z): 30.0
```



NO 8

```
from pulp import LpProblem, LpVariable, LpMaximize


model = LpProblem(name="Maximize_the_profit_in_production_process", sense=LpMaximize)



x1 = LpVariable(name=("x1"), lowBound=0)
x2 = LpVariable(name=("x2"), lowBound=0)

#defining the objective function

model += 5 * x1 + 3 * x2

#defining the constraints

model += 2 * x1 + 3 * x2 <= 60 #labors in hours
model += 4 * x1 + 2 * x2 <= 80 # Raw materials in units

#solve the probleM

model.solve()


print("Optimal value:")
print(f"Quantity of product 1 to produce (x1): {x1.varValue}")
print(f"Quantity of product 2 to produce (x2): {x2.varValue}")
print(f"maximum value(Z): {model.objective.value()}")

Optimal value:
Quantity of product 1 to produce (x1): 15.0
Quantity of product 2 to produce (x2): 10.0
maximum value(Z): 105.0




import matplotlib.pyplot as plt
import numpy as np

# defining the x array

x = np.linspace(0,50,20000)
```

```
#  convert the constraints to inequalities

y1 = (60-2*x)/3
y2 = (80-4*x)/2

# plot the the constraints

plt.plot(x,y1,label="2 * x1 + 3 * x2 <= 60")
plt.plot(x,y2,label="4 * x1 + 2 * x2 <= 80")

# shading the feasible region

y3 = np.minimum.reduce([y1,y2])
plt.fill_between(x,y3,0 ,label="feasible region", color="gray",alpha=0.5)

#optimal solution

optimal_x1 = 15.0
optimal_x2 = 10.0
plt.plot(optimal_x1, optimal_x2, "ro", markersize=8, label="optimal_solution")

# plt.plot(15,10,"ro", markersize=8, color="red", label="optimal point")

plt.xlabel("Quantity of product 1 to produce: x-axis")
plt.ylabel("Quantity of product 1 to produce: y-axis")
plt.title("feasible region and optimal solution")
plt.xlim(0,40)
plt.ylim(0,50)
plt.grid(True)
plt.legend()
plt.show()
```


feasible region and optimal solution
2 * x1 + 3 * x2 <= 60
4 * x1 + 2 * x2 <= 80
feasible region
optimal_solution
Quantity of product 1 to produce: y-axis
Quantity of product 1 to produce: x-axis
0
10
20
30
40
50
0
5
10
15
20
25
30
35
40