

## **Experiment-1:**

### Study of Optimization in Engineering Problems

**Aim:** To study optimization problems in different engineering fields and identify objective functions, decision variables, and constraints.

## Theoretical Background

Optimization is the process of finding the **best possible solution** to a problem under given conditions.

An optimization problem generally consists of:

1. **Decision Variables**  
Variables whose values are to be determined (e.g., dimensions, quantities, time).
2. **Objective Function**  
A mathematical function representing the goal of optimization (minimization or maximization).
3. **Constraints**  
Restrictions or limitations on decision variables (equality or inequality constraints).

## General Mathematical Form

### General Mathematical Form

Optimize  $f(x_1, x_2, \dots, x_n)$

subject to

$$g_i(x_1, x_2, \dots, x_n) \leq / = / \geq b_i$$

Engineering optimization problems arise in:

- Mechanical engineering (minimum weight design)
- Electrical engineering (minimum power loss)
- Civil engineering (minimum construction cost)
- Production engineering (maximum profit)

## Example 1: Mechanical Engineering

### R Code

```
1 # #####
2 # Experiment 1: Study of Optimization Problems in Engineering
3 # Identification of decision variables, objective function
4 # and constraints for real-life engineering problems
5 # #####
6
7 cat("EXPERIMENT 1: STUDY OF OPTIMIZATION PROBLEMS IN ENGINEERING\n\n")
8
9 # #####
10 # 1. Mechanical Engineering Problem
11 # Minimize weight of a beam
12 # #####
13
14 cat("1. Mechanical Engineering Problem: Beam Design\n")
15
16 # Decision Variables
17 length <- 5 # meters
18 area <- 0.02 # m^2
19 density <- 7850 # kg/m^3 (steel)
20
21 # Constraint variables (define FIRST)
22 stress <- 200 # MPa
23 stress_limit <- 250 # MPa
24
25 # Objective Function
26 weight <- density * area * length
27
28 cat("Decision Variables: length, area\n")
29 cat("Objective Function: Minimize Weight\n")
30 cat("Weight of Beam =", weight, "kg\n")
31
32 cat("Constraint: Stress <=", stress_limit, "MPa\n")
33 cat("Stress Satisfied:", stress <= stress_limit, "\n\n")
34
```

## Output

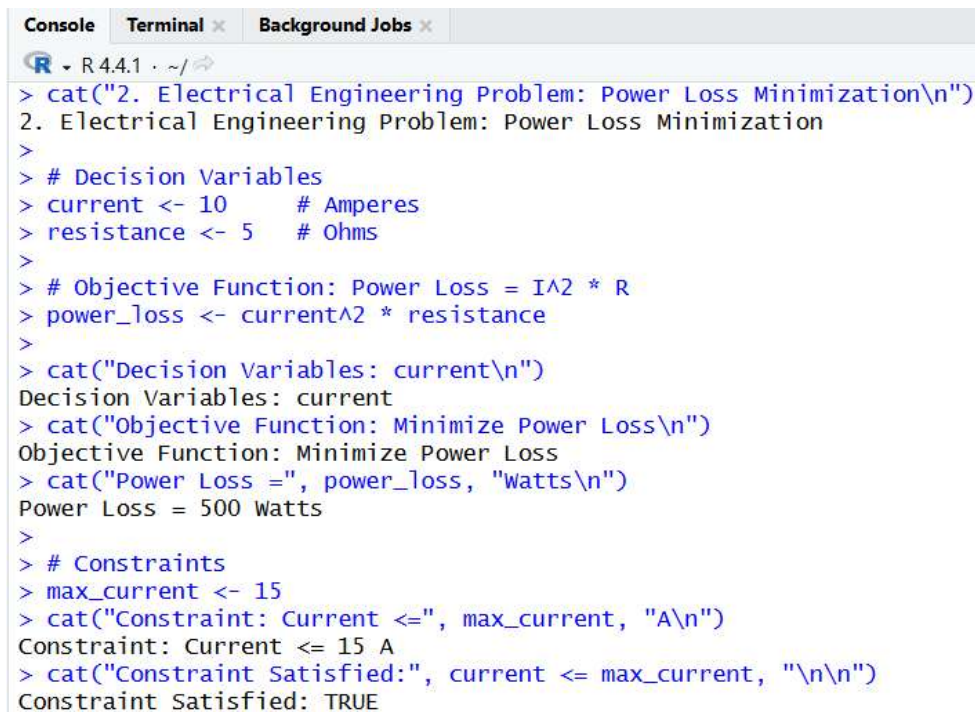
```
Console Terminal x Background Jobs x
R • R 4.4.1 • ~/
> cat("1. Mechanical Engineering Problem: Beam Design\n")
1. Mechanical Engineering Problem: Beam Design
>
> # Decision Variables
> length <- 5          # meters
> area <- 0.02         # m^2
> density <- 7850      # kg/m^3 (steel)
>
> # Constraint variables (define FIRST)
> stress <- 200        # MPa
> stress_limit <- 250  # MPa
>
> # Objective Function
> weight <- density * area * length
>
> cat("Decision Variables: length, area\n")
Decision Variables: length, area
> cat("Objective Function: Minimize Weight\n")
Objective Function: Minimize Weight
> cat("Weight of Beam =", weight, "kg\n")
Weight of Beam = 785 kg
>
> cat("Constraint: Stress <=", stress_limit, "MPa\n")
Constraint: Stress <= 250 MPa
> cat("Stress Satisfied:", stress <= stress_limit, "\n\n")
Stress Satisfied: TRUE
```

## Example 2: Electrical Engineering

### R Code

```
#####  
# 2. Electrical Engineering Problem  
# Minimize power loss in transmission line  
#####  
  
cat("2. Electrical Engineering Problem: Power Loss Minimization\n")  
  
# Decision Variables  
current <- 10      # Amperes  
resistance <- 5     # Ohms  
  
# Objective Function: Power Loss = I^2 * R  
power_loss <- current^2 * resistance  
  
cat("Decision Variables: current\n")  
cat("Objective Function: Minimize Power Loss\n")  
cat("Power Loss =", power_loss, "Watts\n")  
  
# Constraints  
max_current <- 15  
cat("Constraint: Current <=", max_current, "A\n")  
cat("Constraint Satisfied:", current <= max_current, "\n\n")
```

### Output



```
R - R 4.4.1 - ~/...  
> cat("2. Electrical Engineering Problem: Power Loss Minimization\n")  
2. Electrical Engineering Problem: Power Loss Minimization  
>  
> # Decision Variables  
> current <- 10      # Amperes  
> resistance <- 5     # Ohms  
>  
> # Objective Function: Power Loss = I^2 * R  
> power_loss <- current^2 * resistance  
>  
> cat("Decision Variables: current\n")  
Decision Variables: current  
> cat("Objective Function: Minimize Power Loss\n")  
Objective Function: Minimize Power Loss  
> cat("Power Loss =", power_loss, "Watts\n")  
Power Loss = 500 Watts  
>  
> # Constraints  
> max_current <- 15  
> cat("Constraint: Current <=", max_current, "A\n")  
Constraint: Current <= 15 A  
> cat("Constraint Satisfied:", current <= max_current, "\n\n")  
Constraint Satisfied: TRUE
```



## Example 3: Civil Engineering

### R Code

```
58 - #####
59 # 3. Civil Engineering Problem
60 # Minimize construction cost
61 - #####
62
63 cat("3. Civil Engineering Problem: Construction Cost Minimization\n")
64
65 # Decision Variables|
66 cement <- 300 # kg
67 steel <- 100 # kg
68
69 # Objective Function: Total Cost
70 cost <- 7 * cement + 60 * steel
71
72 cat("Decision Variables: cement, steel\n")
73 cat("Objective Function: Minimize Construction Cost\n")
74 cat("Total Cost = Rs.", cost, "\n")
75
76 # Constraints
77 min_strength <- 400
78 strength <- 450
79
80 cat("Constraint: Strength >=", min_strength, "\n")
81 cat("Strength Satisfied:", strength >= min_strength, "\n\n")
82
```

### Output

Console	Terminal x	Background Jobs x
R • R 4.4.1 • ~/		
> cat("3. Civil Engineering Problem: Construction Cost Minimization\n")		
3. Civil Engineering Problem: Construction Cost Minimization		
>		
> # Decision Variables		
> cement <- 300 # kg		
> steel <- 100 # kg		
>		
> # Objective Function: Total Cost		
> cost <- 7 * cement + 60 * steel		
>		
> cat("Decision Variables: cement, steel\n")		
Decision Variables: cement, steel		
> cat("Objective Function: Minimize Construction Cost\n")		
Objective Function: Minimize Construction Cost		
> cat("Total Cost = Rs.", cost, "\n")		
Total Cost = Rs. 8100		
>		
> # Constraints		
> min_strength <- 400		
> strength <- 450		
>		
> cat("Constraint: Strength >=", min_strength, "\n")		
Constraint: Strength >= 400		
> cat("Strength Satisfied:", strength >= min_strength, "\n\n")		
Strength Satisfied: TRUE		

## Example 4: Industrial Engineering

### R Code

```
83 # #####
84 # 4. Production / Industrial Engineering Problem
85 # Maximize profit
86 # #####
87
88 cat("4. Production Engineering Problem: Profit Maximization\n")
89
90 # Decision Variables
91 x <- 40 # units of product A
92 y <- 30 # units of product B
93
94 # Objective Function: Profit
95 profit <- 50 * x + 40 * y
96
97 cat("Decision Variables: x (Product A), y (Product B)\n")
98 cat("Objective Function: Maximize Profit\n")
99 cat("Total Profit = Rs.", profit, "\n")
100 |
101 # Constraints
102 machine_hours <- 120
103 used_hours <- 2 * x + y
104
105 cat("Constraint: Machine Hours <=", machine_hours, "\n")
106 cat("Used Hours =", used_hours, "\n")
107 cat("Constraint Satisfied:", used_hours <= machine_hours, "\n")
108
109 cat("\nExperiment 1 completed successfully.\n")
```

## Output

```
Console Terminal x Background Jobs x
R - R 4.4.1 - ~/
> cat("4. Production Engineering Problem: Profit Maximization\n")
4. Production Engineering Problem: Profit Maximization
>
> # Decision Variables
> x <- 40 # units of product A
> y <- 30 # units of product B
>
> # Objective Function: Profit
> profit <- 50 * x + 40 * y
>
> cat("Decision Variables: x (Product A), y (Product B)\n")
Decision Variables: x (Product A), y (Product B)
> cat("Objective Function: Maximize Profit\n")
Objective Function: Maximize Profit
> cat("Total Profit = Rs.", profit, "\n")
Total Profit = Rs. 3200
>
> # Constraints
> machine_hours <- 120
> used_hours <- 2 * x + y
>
> cat("Constraint: Machine Hours <=", machine_hours, "\n")
Constraint: Machine Hours <= 120
> cat("Used Hours =", used_hours, "\n")
Used Hours = 110
> cat("Constraint Satisfied:", used_hours <= machine_hours, "\n")
Constraint Satisfied: TRUE
>
> cat("\nExperiment 1 completed successfully.\n")

Experiment 1 completed successfully.
```

## Practice Questions

1. Modify the beam design code to include an additional constraint on the maximum length.

### R Code



```

1 #####
2 # Practical Q1: Beam Design with Maximum Length Constraint
3 #####
4
5 cat("Practical 1: Beam Design with Maximum Length Constraint\n")
6
7 # Decision Variables
8 length <- 5          # meters
9 area <- 0.02         # m^2
10 density <- 7850      # kg/m^3
11
12 # Constraints
13 stress <- 200        # MPa
14 stress_limit <- 250  # MPa
15 max_length <- 6      # meters
16
17 # Objective Function
18 weight <- density * area * length
19
20 # Output
21 cat("Objective Function: Minimize Weight\n")
22 cat("Weight of Beam =", weight, "kg\n")
23
24 cat("Constraint 1: Stress <=", stress_limit, "MPa\n")
25 cat("Stress Satisfied:", stress <= stress_limit, "\n")
26
27 cat("Constraint 2: Length <=", max_length, "m\n")
28 cat("Length Satisfied:", length <= max_length, "\n")
29

```

## Output

```

> #####
> # Practical Q1: Beam Design with Maximum Length Constraint
> #####
>
> cat("Practical 1: Beam Design with Maximum Length Constraint\n")
Practical 1: Beam Design with Maximum Length Constraint
>
> # Decision Variables
> length <- 5          # meters
> area <- 0.02         # m^2
> density <- 7850      # kg/m^3
>
> # Constraints
> stress <- 200        # MPa
> stress_limit <- 250  # MPa
> max_length <- 6      # meters
>
> # Objective Function
> weight <- density * area * length
>
> # Output
> cat("Objective Function: Minimize Weight\n")
Objective Function: Minimize Weight
> cat("Weight of Beam =", weight, "kg\n")
Weight of Beam = 785 kg
>
> cat("Constraint 1: Stress <=", stress_limit, "MPa\n")
Constraint 1: Stress <= 250 MPa
> cat("Stress Satisfied:", stress <= stress_limit, "\n")
Stress Satisfied: TRUE

```

```

>
> cat("Constraint 2: Length <=", max_length, "m\n")
Constraint 2: Length <= 6 m
> cat("Length Satisfied:", length <= max_length, "\n")
Length Satisfied: TRUE
> |

```

2. Change the objective from minimizing weight to minimizing cost by including material cost per kg.

## R Code

```

1 #####
2 # Practical Q2: Beam Cost Minimization
3 #####
4
5 cat("Practical 2: Beam Cost Minimization\n")
6
7 # Decision Variables
8 length <- 5          # meters
9 area <- 0.02         # m^2
10 density <- 7850      # kg/m^3
11 cost_per_kg <- 60    # Rs per kg
12
13 # Objective Function
14 weight <- density * area * length
15 cost <- weight * cost_per_kg
16
17 # Constraint
18 stress <- 200
19 stress_limit <- 250
20
21 # Output
22 cat("Objective Function: Minimize Cost\n")
23 cat("Total Weight =", weight, "kg\n")
24 cat("Total Cost = Rs.", cost, "\n")
25
26 cat("Stress Constraint Satisfied:", stress <= stress_limit, "\n")
27

```

## Output

```

> # Practical Q2: Beam Cost Minimization
> #####
>
> cat("Practical 2: Beam Cost Minimization\n")
Practical 2: Beam Cost Minimization
>
> # Decision Variables
> length <- 5          # meters
> area <- 0.02          # m^2
> density <- 7850       # kg/m^3
> cost_per_kg <- 60     # Rs per kg
>
> # Objective Function
> weight <- density * area * length
> cost <- weight * cost_per_kg
>
> # Constraint
> stress <- 200
> stress_limit <- 250
>
> # Output
> cat("Objective Function: Minimize Cost\n")
Objective Function: Minimize Cost
> cat("Total Weight =", weight, "kg\n")
Total Weight = 785 kg
> cat("Total Cost = Rs.", cost, "\n")
Total Cost = Rs. 47100
>
> cat("Stress Constraint Satisfied:", stress <= stress_limit, "\n")
Stress Constraint Satisfied: TRUE

```

3. Create an R program that models an electrical power loss minimization problem.

#### R Code

```

1 #####
2 # Practical Q3: Electrical Power Loss Minimization
3 #####
4
5 cat("Practical 3: Electrical Power Loss Minimization\n")
6
7 # Decision Variables
8 current <- 10        # Amperes
9 resistance <- 5       # Ohms
10
11 # Objective Function
12 power_loss <- current^2 * resistance
13
14 # Constraint
15 max_current <- 15
16
17 # Output
18 cat("Objective Function: Minimize Power Loss\n")
19 cat("Power Loss =", power_loss, "Watts\n")
20
21 cat("Constraint: Current <=", max_current, "A\n")
22 cat("Constraint Satisfied:", current <= max_current, "\n")
23

```

#### Output

```

> #####
> # Practical Q3: Electrical Power Loss Minimization
> #####
>
> cat("Practical 3: Electrical Power Loss Minimization\n")
Practical 3: Electrical Power Loss Minimization
>
> # Decision Variables
> current <- 10      # Amperes
> resistance <- 5     # Ohms
>
> # Objective Function
> power_loss <- current^2 * resistance
>
> # Constraint
> max_current <- 15
>
> # Output
> cat("Objective Function: Minimize Power Loss\n")
Objective Function: Minimize Power Loss
> cat("Power Loss =", power_loss, "Watts\n")
Power Loss = 500 Watts
>
> cat("Constraint: Current <=", max_current, "A\n")
Constraint: Current <= 15 A
> cat("Constraint Satisfied:", current <= max_current, "\n")
Constraint Satisfied: TRUE

```