Ages 14 - 19

Design Thinking | Empathize

Programming & Coding | Problem Solving

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Optimize, Design, and Minimize

Mathematics

120 min

Intel® Core™ processors

Overview

- Understand the role of packaging design in sustainable product development and its impact on material efficiency.
- Apply Linear Programming to determine the optimal number of laptop boxes that can be cut from large cardboard sheets.
- Learn how to use differentiation in order to solve optimization problems.

Unboxing: What happens to the packaging?

Unboxing a new gadget is exciting, but what happens to all that packaging once you're done?

Packaging Materials

Packaging often includes **foam, cardboard, and plastic**, all of which can harm the environment.

The Problem

- Although cardboard is decomposable, the plastic and foam used in packaging are not, contributing to long-term environmental issues.
- A large amount of packaging materials ends up in landfills, where non-decomposable materials persist for years, impacting the environment and releasing harmful substances.

What can be done to solve this problem?

Acer's Sustainable Packaging Journey

Source: https://www.youtube.com/watch?v=YGnTprEWek0&

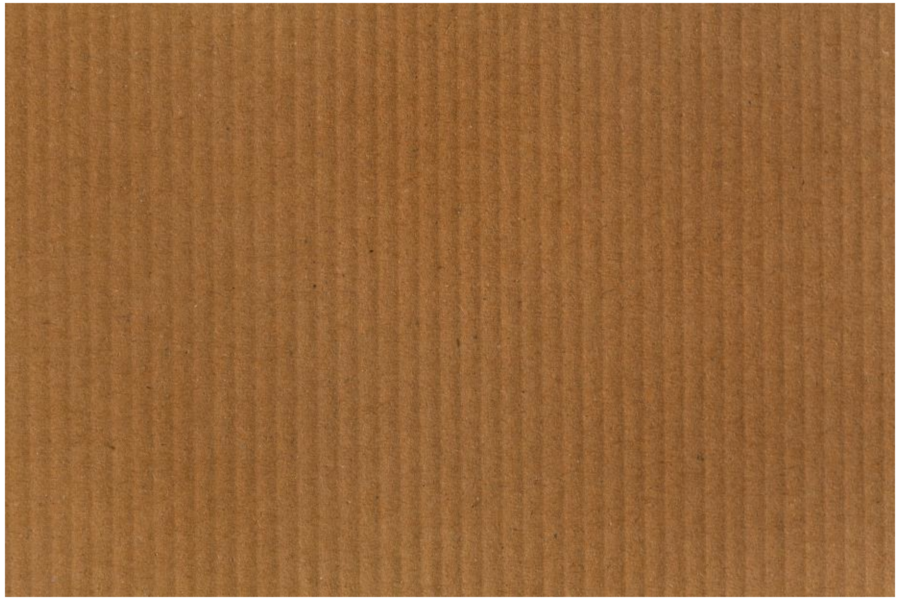
The Problem

- Acer uses recyclable materials for packaging, replacing plastic and foam while ensuring protection.
- The design focuses on eco-friendly innovation, enhancing both functionality and sustainability.

Looking Ahead: **Optimizing** cardboard sheet usage can further minimize waste and cost while maintaining product protection for various laptop sizes.

Introduction to Optimization

Time to Think!



- You have a large cardboard sheet measuring 200 cm x 200 cm.
- You need to cut out squares of different sizes (e.g., 20 cm x 20 cm, 30 cm x 30 cm) from the sheet.
- **How would you determine** whether to cut squares of similar sizes or a mix of sizes, and how can you maximize the number of squares cut while minimizing waste?

Optimization

- Optimization involves finding the best solution from various options while adhering to specific constraints.
- It focuses on maximizing or minimizing objectives like profit, efficiency, or cost.
- It is used in various fields and often involves mathematical models to determine the best outcome.
- There are multiple methods to solve optimization problems, but we will focus on **linear programming and derivatives.**

Introduction to Linear Programming (LP)

Linear Programming

Linear Programming is a mathematical method for determining the best outcome (such as maximum profit or minimum cost) in a model whose requirements are represented by linear relationships.

In a typical LP problem:

- **The Objective Function** defines what needs to be optimized (maximized or minimized).
- **Constraints** set the boundaries within which the solution must lie, ensuring the solution is feasible and practical.

Objective

Objective

$$z = c_1x_1 + c_2x_2 + \dots + c_n\, x_n$$

- z is the value to be optimized (e.g., profit, cost).
- $c_1, c_2, \dots, c_n$ are coefficients representing the contribution of each decision variable $x_1, x_2, \dots, x_n$ to the objective.
- $x_1, x_2, \dots, x_n$ are the decision variables whose values are to be determined.

Constraints

Constraint

$$a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \leq b_1$$

- a_{ij} are coefficients that define the relationship between the decision variables x_j and the i-th constraint.
- There can be multiple constraints.
- $b_1, b_2, \ldots, b_m$ are constants representing the upper or lower bounds for each constraint.

Example

Maximize

$$z = 3x_1 + 6x_2$$

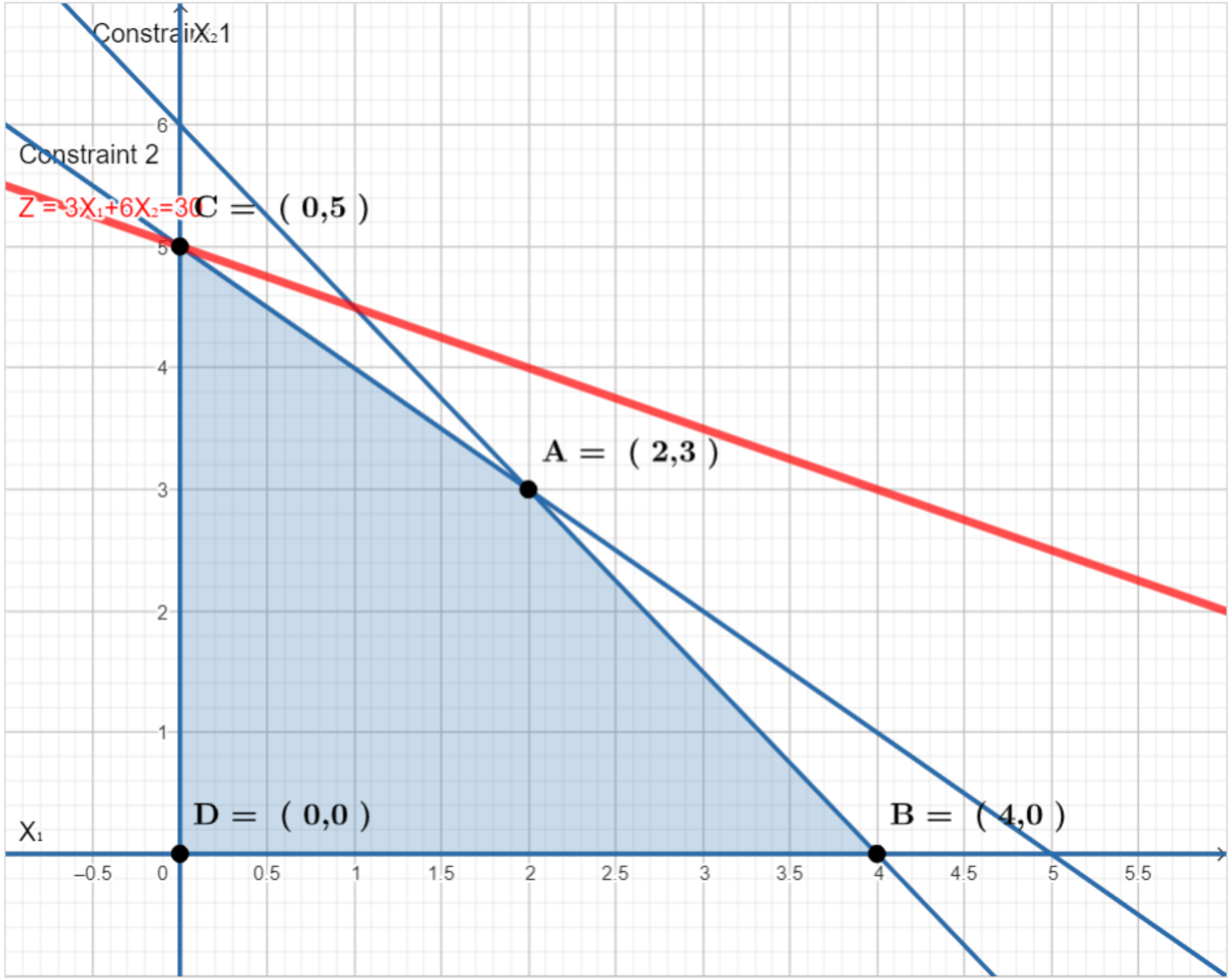
Subject To

$$3x_1 + 2x_2 \leq 12$$

$$x_1 + x_2 \leq 5$$

$$x_1, x_2 \geq 0$$

Solution



Look at the graph and determine the maximum value of Z.

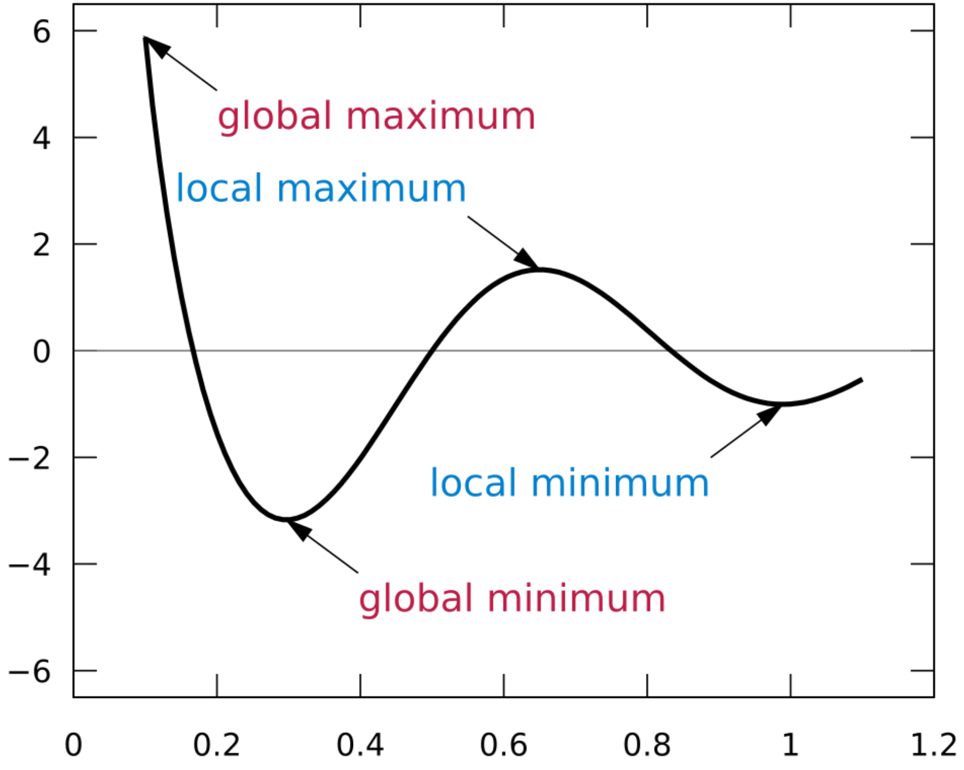
Did You Know?

- Linear programming can find the best routes for delivery trucks to minimize travel distance and fuel costs.
- UPS (United Parcel Service) used linear programming to optimize its delivery routes for package distribution, resulting in potential annual savings of **$180,000** in fueling costs.

Source: https://ieeexplore.ieee.org/abstract/document/149716

Optimization using Derivatives

Derivatives Basics



First Derivative $f'(x)$:

- Measures how the function changes with respect to x.
- Critical Points: Where $f'(x) = 0$ $f'(x)$ is undefined. These points are potential candidates for local maxima or minima.

Optimization Using Derivatives

1. Define the Function: Identify the function $f(x)$ you want to optimize.
2. Compute the First Derivative: Find $f'(x)$.
3. Solve for Critical Points: Set $f'(x) = 0$ to find points where the function's slope is zero.
4. Evaluate the Function: Compare the values of the function at these critical points to determine the optimal solution.

Optimization Using Derivatives: Example

1. Define the Profit Function: Let $P(x)$ be the profit function where x is the number of units sold.

Example function: $\mathbf{P(x) = -5x^2 + 300x - 2000}$, $-5x^2$ represents the decrease in profit due to increased production costs. $300x$ represents the revenue from sales. -2000 represents fixed costs.

2. Compute the First Derivative: Find $P'(x)$, the rate of change of profit with respect to units sold. For the above function:

$$P'(x) = -10x + 300$$

Optimization Using Derivatives: Example

3. Solve for Critical Points: Set $P'(x)$=0 to find the critical point.

$-10x + 300 = 0$

Solve for x: $x = 30$

4. Evaluate the Function: Determine the profit at x=30.

Calculate $P(30)$ to find the maximum profit.

The optimal **number of units to produce is 30**, which maximizes the profit.

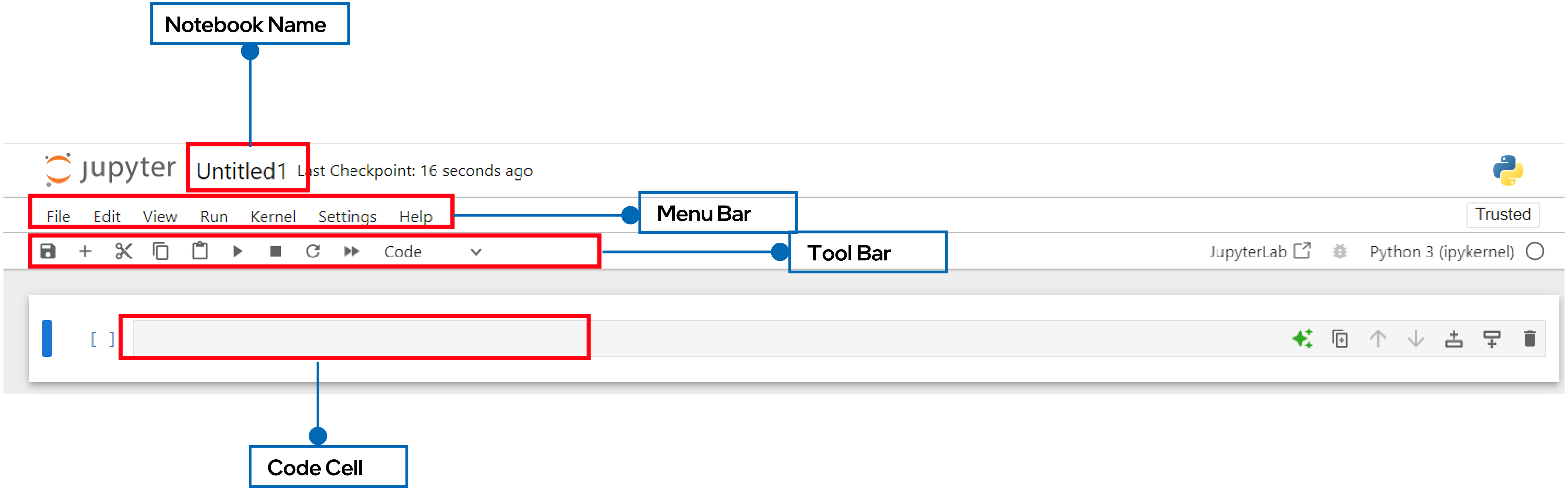
Solving a few equations by hand is manageable, but what do you do when you're faced with dozens of equations? How can you efficiently find the best solution?

Python

- Use Programming: Automate the solving process with programming languages like Python, which can handle complex calculations and large systems of equations.
- **Python** offer libraries (e.g., NumPy, SciPy, and PuLP) that have built-in functions to solve linear equations and perform linear programming tasks.

Demonstration of Python and Jupyter Notebook

Jupyter Notebook: User Interface



Your Mission

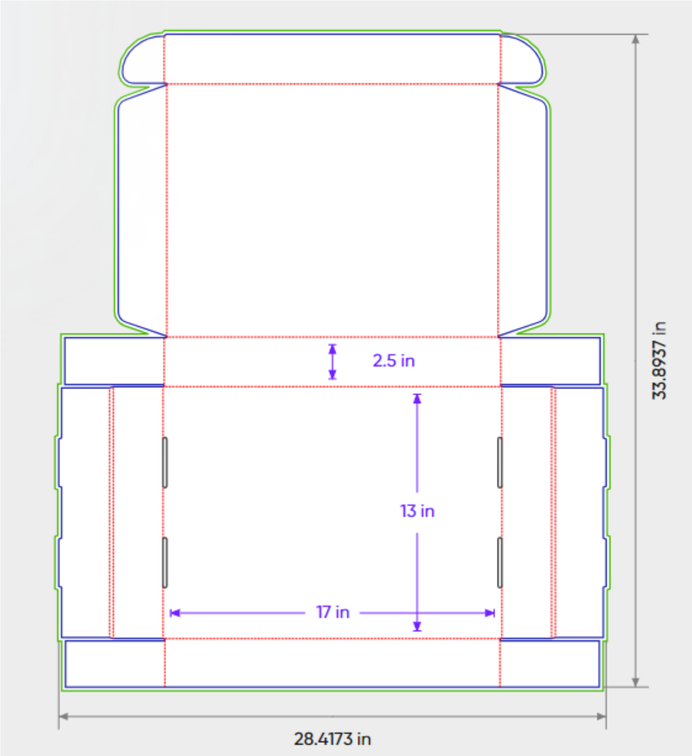
Mission 1: Optimal Laptop Boxes - Determine how many 13-inch laptop boxes can be cut from 8x5 feet cardboard sheets to maximize box count and minimize waste.

Mission 2: Cardboard Sheet Optimization - Use Linear Programming to find the best arrangement for different-sized boxes on large cardboard sheets to reduce waste and maximize material use.

Mission 3: Maximizing Box Volume - Optimize the dimensions of a box made by cutting squares from a flat sheet and folding it, aiming to maximize the box's volume for efficient packaging.

Dieline

A dieline is a template or blueprint used in the packaging industry to ensure that the design of a package fits perfectly on the material (such as cardboard) when it is cut, folded, and assembled.



Let’s Practice!

Summary

- Understood the role of packaging design in sustainable product development and its impact on material efficiency.
- Applied Linear Programming to determine the optimal number of laptop boxes that can be cut from large cardboard sheets.
- Applied derivatives to calculate the dimensions of a box with maximum volume.

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