University of Engineering and Technology, Lahore

Department of Computer Science

Project Report

Team Members

Name	Roll Number	Email
Shahram Ali Butt	2025-CS-20	shahramalibutt@gmail.com

Session: Fall’25 Morning/Evening   Section: A   Semester: 1st

Course: CSC101 - Discrete Mathematics   Teacher: Mr. Waqas Ali

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Project Report

Submission Deadline: January 6, 2026

1. Project Title

Password Security Mechanism, *Design and Implementation using Discrete Mathematics*

2. Chosen Track

Track 5: Number Theory Applications

3. Overview

This project shows the practical application of discrete mathematics concepts, specifically cryptography and number theory, to solve a real-world security problem. The system implements multiple classic encryption algorithms including Caesar cipher, Vigenère cipher, Affine cipher, and a custom hash function to secure user credentials.

The motivation for this project was a business application where passwords were initially stored in plain text format, which was a security vulnerability. By applying cryptographic techniques. The system now encrypts all sensitive data before storage, demonstrating the practical use of Discrete mathematics concepts in computer science.

4. Summary

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5. Technology Stack & Libraries Utilized

- **Programming Languages:** C++ 23
- **Libraries:** iostream, fstream, sstream, limits, cmath
- **Development Environment:** gitbash, VSCode

6. Problem Statement

In the initial version of a business inventory management application, user credentials were stored insecurely:

- Admin password was hardcoded directly in the source code
- User passwords were stored in plain text in external files
- Anyone with access to the code or files could view all passwords
- No encryption or security measures were implemented

7. Objectives

Primary Objectives:

- Implement multiple classical cryptographic algorithms using discrete mathematics
- Secure password storage through encryption techniques
- Demonstrate practical application of modular arithmetic and number theory
- Create an interactive system for testing different encryption methods

Secondary Objectives:

- Provide educational demonstrations of each cryptographic method
- Implement password verification without storing plain text
- Integrate encryption into existing business application

8. Mathematical Foundations

The project is built upon many concepts from discrete mathematics, specifically from Chapters 4 and 5 of Rosen's textbook:

9. Examination of Key Functions/Methods

9.1 Caesar Cipher

Mathematical Concept:

The Caesar cipher is a substitution cipher that shifts each letter by a fixed number of positions in the alphabet using modular arithmetic.

Encryption Formula:

E(x) = (x + shift) mod 26

Decryption Formula:

D(x) = (x - shift) mod 26

Example:

Plain text: HELLO

Shift: 3

Cipher text: KHOOR

9.2 Vigenère Cipher

Mathematical Concept:

A polyalphabetic substitution cipher that uses a keyword to determine different shifts for each character position.

Encryption Formula:

$E(x) = (x + k[i \bmod |k|]) \bmod 26$

Decryption Formula:

$D(x) = (x - k[i \bmod |k|]) \bmod 26$

Example:

Plain text: HELLO
Key: KEY
Cipher text: RIJVS

9.3 Affine Cipher

Mathematical Concept:

Uses two keys (a, b) with modular arithmetic. Requires understanding of coprime numbers and modular multiplicative inverse.

Encryption Formula:

$E(x) = (a \times x + b) \bmod 26$

Decryption Formula:

$D(x) = a^{-1} \times (x - b) \bmod 26$

Requirement:

$\gcd(a, 26) = 1$ (a must be coprime with 26)

Valid values for a:

1, 3, 5, 7, 9, 11, 15, 17, 19, 21, 23, 25

9.4 Hash Function

Mathematical Concept:

A one-way function that maps data of arbitrary size to fixed-size values using modular arithmetic and prime numbers.

Formula:

hash = Σ(char[i] × prime^i) mod large_prime

Properties:

- Deterministic: Same input always produces same output
- One-way: Cannot reverse the hash to get original password
- Fixed output size regardless of input length

9.5 Supporting Mathematical Concepts

Greatest Common Divisor (GCD):

Used to verify coprimality in Affine cipher. Implemented using Euclidean algorithm.

Modular Multiplicative Inverse:

Essential for Affine cipher decryption. For a and m coprime, find x where $(a \times x) \bmod m = 1$.

Modular Arithmetic:

Foundation of all cipher operations. Ensures values wrap around within a fixed range (0-25 for alphabet).

10. System Design and Implementation

The system consists of three main components:

- **crypto_functions.h/cpp:** Core cryptographic algorithms and helper functions
- **main.cpp:** Interactive menu system for demonstrations and testing
- **passwordManagement.cpp:** Integration with business application

11. Business Application Integration

The passwordManagement.cpp file implements several critical functions for the business application:

- **storeUserDataEnc():** Encrypts usernames using Affine cipher (a=5, b=8) and stores with hashed passwords
- **verifyUser():** Decrypts stored usernames and compares hashed passwords for authentication
- **verifyAdmin():** Double-hashes admin password for additional security
- **storeSignUpDataEnc():** Encrypts signup requests using different Affine keys (a=9, b=15)
- **loadSignUpDataDec():** Decrypts signup data for admin review
- **checkUserExists():** Verifies if username already exists without storing plain text

12. System Features

12.1 Interactive Menu System

The main program provides an intuitive menu-driven interface with the following options:

- Individual encryption for each cipher type
- Password hashing functionality
- Cipher combination feature (joining two encryption methods)
- Comprehensive demonstrations of all methods
- Built-in explanations for each cryptographic technique

12.2 Cipher Combination Feature

Unique feature allowing users to combine two encryption methods for enhanced security:

- Caesar + Vigenère
- Caesar + Affine
- Vigenère + Affine

This demonstrates how multiple mathematical transformations can be composed for stronger encryption.

12.3 Educational Explanations

Each encryption method includes:

- Step-by-step explanation of how it works
- Mathematical formulas
- Practical examples
- Known limitations and vulnerabilities

13. Results and Testing

13.1 Test Cases and Validation

Comprehensive testing was performed on all cryptographic functions:

Method	Input	Encrypted	Status
Caesar (shift=3)	HelloWorld	KhoorZruog	✓ Pass
Vigenère (key=KEY)	HelloWorld	RijvsUyvjn	✓ Pass
Affine (a=5, b=8)	HelloWorld	RcllaOaplx	✓ Pass
Hash Function	MyPassword123	972352	✓ Pass

All encryption and decryption operations successfully reversed to original text, confirming mathematical correctness.

13.2 Business Application Integration Results

The password management system was successfully integrated into the business application with the following results:

- All usernames encrypted with Affine cipher before storage
- All passwords hashed before storage
- Admin password receives double-hashing for extra security
- Successful authentication without storing plain text
- Signup requests encrypted with different keys to segregate data

14 Limitations

As an educational project, the system has certain limitations:

- Caesar cipher vulnerable to frequency analysis
- Vigenère cipher can be broken with sufficient ciphertext
- Affine cipher has limited key space
- Hash function not cryptographically secure

15. Conclusion

This project demonstrates the role of discrete mathematics in computer security. By implementing multiple cryptography techniques, I transformed an insecure system storing plain text passwords into a secure application.

The system integrates into a business application, proving that theoretical mathematical knowledge directly translates to practical problem-solving in software development. The implementations are educational only and not production-ready.

16. References

- Rosen, K. H. (2019). Discrete Mathematics and Its Applications (8th ed.). McGraw-Hill Education. Chapter 4: Number Theory and Cryptography.
- Rosen, K. H. (2019). Discrete Mathematics and Its Applications (8th ed.). McGraw-Hill Education. Chapter 5: Induction and Recursion.
- Tutorial: https://youtu.be/0ZxqLybllNQ?si=DYgdY62lqGmirxEB
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