

## CIS 3362 Final Exam Review

**Date:** 12/8/2021 (Wednesday)

**Time:** 10:00 am – 12:50 pm

**Format:** Written, Short Answer, Problems

**Exam Aids:** Four Sheets of Typed/Written Notes - You Bring  
Reference sheets (Exam 1, DES, AES) - I provide  
Calculator -You Bring

**If you need a make up, you need to tell me BEFORE the exam. (Depending on the situation and timing, I will either do the make up before finals end, or assign an incomplete and give the final when it makes sense.)**

### Mathematical Tools

Euclidean Algorithm

Extended Euclidean Algorithm

Index of Coincidence

Mutual Index of Coincidence

Prime Number Definition

Fermat's Theorem

Euler Phi Function

Primitive Roots of a Prime

Discrete Log Problem

Miller-Rabin Primality Checking Algorithm

Fermat Factoring

Pollard-Rho Factoring

Discrete Log Problem

Fast Modular Exponentiation

## **Classical Cryptography Part I**

Shift Cipher

Affine Cipher

Substitution Cipher

Vigenere Cipher

## **Classical Cryptography Part II**

Playfair

ADFGVX

Hill Cipher

Enigma

Navajo Code

Transposition

## **Modern Symmetric Ciphers**

Bitwise operators

DES

AES

## **Public Key Cryptography**

Diffie-Hellman

RSA

El Gamal

ECC

## **Odds and Ends**

Quantum Cryptography

Group Diffie-Hellman

Hash Functions, Salting Passwords

Birthday Attack

Probability Problems Associated with Birthday Attack

Use of RSA twice for Digital Signature

El Gamal Digital Signature

## Some Past Final Exam Questions

1) In a set of 100 bits (zeroes and ones), the index of coincidence is  $\frac{19}{33}$ . Let  $x$  be the number of 0s in the set and  $y$  be the number of 1s in the set. What is  $|x - y|$ ?

2) Consider an affine cipher for an alphabet of size 65 with the encryption function  
$$f(x) = 28x + 33 \pmod{65}$$

Determine the corresponding decryption function  $f^{-1}(x)$ .

3) Consider the following IP matrix for a DES-like cipher with a block size of 16 bits:

$$IP = \begin{bmatrix} 14 & 9 & 8 & 3 \\ 6 & 12 & 1 & 11 \\ 16 & 7 & 5 & 15 \\ 2 & 4 & 10 & 13 \end{bmatrix}$$

If the input to the IP matrix in HEX is 4F79, what is the output, represented in HEX?

4) What is the result of the multiplication  $03 \times B6$ , in the AES field? In order to get credit, you must show all of your work by hand.

5) A generator,  $g$ , of a prime  $p$  is a number such that the set  $\{g^1 \pmod{p}, g^2 \pmod{p}, \dots, g^{p-1} \pmod{p}\}$  contains each of the integers from 1 to  $p-1$  precisely once. We will call a half-generator,  $g$ , of a prime number  $p$  a number such that the set  $\{g^1 \pmod{p}, g^2 \pmod{p}, \dots, g^{p-1} \pmod{p}\}$  contains half of the integers from 1 to  $p-1$  precisely twice. How many half generators are there for a prime  $p$ ? Please give your answer in terms of the Euler phi function and  $p$  with a rationale for your answer. (Note: This one is challenging, but the answer can be derived from the reasoning behind counting the number of generators of a prime  $p$ , using a particular generator,  $g$ .)

6) (15 pts) One way to calculate  $\phi(n)$  is to find each unique prime number,  $p_i$  that is a factor of  $n$ , and multiply  $n$  by each term of the form  $(p_i - 1)/p_i$ . Notice that since  $p_i$  is a divisor of  $n$ , one can first do the division and then the multiplication and the answer will be accurate without risk of overflow. In the algorithm we maintain two “accumulators” a running value of  $n$  and a running value of  $\phi$ . Both are initialized to  $n$  and both will get reduced in different ways over the course of the algorithm, which is described below.

Consider using this algorithm to calculate  $\phi(300)$ . We first discover that 2 is a prime factor of 300. So take 300 and multiply by  $1/2$ , yielding 150, our running value of  $\phi$ . In addition, divide out each factor of 2 from 300 to yield 75, what remains after dividing out each copy of 2, our running value of  $n$ . Next, we discover that 3 is a prime factor of 75. Thus, we take 150 and multiply by  $2/3$  yielding 100. In addition, we take 75 and divide out all copies of 3, yielding 25. Finally, we find that 5 is a prime factor of 25, so we multiply 100 by  $4/5$  yielding 80. Once we divide out all copies of 5 from 25 and get 1, we find that we are done. It follows that  $\phi(300) = 80$ , which is what our function should return in this instance.

In some instances, we will be left with a prime number instead of 1. Consider, if after dividing by 5 we had 37 left. Then, after dividing by 6, we see that we’ve tried all values less than or equal to the square root of 37, so we know there’s no point in continuing the trial division. In this case, we would multiply our running value of  $\phi$  by  $36/37$  after exiting our main loop. (Note: if you continue trial division all the way to  $n$  instead of stopping early and do everything else correct, you’ll earn 12 of 15 points on this question.)

Write a C function that implements the calculation of  $\phi$  using the algorithm described above. (Note: no array is needed for this function, just two accumulator variables and a set of nested loops that do the process described above.

7) Alice and Bob have both set up their own RSA systems and want to use them for both encrypting messages and digital signatures. Both decided it would be easier to perform the double encryption if they both used the same public key  $n$ . What is the problem if they do this?

8) For the purposes of this question, assume that the probability any arbitrary person’s birthday is a particular month is exactly  $\frac{1}{12}$ , for each month. If 4 people are chosen at random, what is the probability that 2 of the people are born in one month and the other 2 people are born in a different month? Express your answer as a fraction in lowest terms.