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RF/JFB

# Opgaver DM595 uge 47/48

Husk at læse de relevante sider i slides og noter før du/I forsøger at løse en opgave.

## I: Løses i løbet af øvelsestimerne i uge 47

1. Suppose in RSA the public key is PK $= (1517, 13)$. Which of the following is the RSA encryption of the message 43?

   (a) $1517^{43} \bmod 13$
   (b) $43^{13} \bmod 1517$
   (c) $13^{43} \bmod 1517$

2. Is one of the following the multiplicative inverse of 49 modulo 221?

   12, 56, 121, 212

3. Which of the following sets of public key (PK) and secret key (SK) is a valid set of RSA keys (ignoring the fact that the numbers are not large enough for security)?

   (a) PK $= (91, 37)$; SK $= (91, 23)$
   (b) PK $= (143, 77)$; SK $= (143, 53)$
   (c) PK $= (231, 59)$; SK $= (231, 47)$
   (d) PK $= (107, 25)$; SK $= (107, 30)$

4. In the Sieve of Eratosthenes (page 33 on the slides), how many lists (including the current) have been created at the point where the number 13 is the first element in a list?

5. We consider the RSA system and use the notation and algorithms from the slides. Let $N = 1517$ and $e = 13$.

   (a) Encrypt the message $m = 43$. For the modular exponentiation, use the algorithm from the slides, page 27. Show all steps of your calculation. How many times during the recursive execution is the "**if** $k$ is odd" case encountered, and how many times is the "**if** $k$ is even" case encountered? [Do not include the base cases $k = 0$ and $k = 1$ in the counts.]

   (b) If you had created the keys yourself, you would know that $p = 37$ and $q = 41$. From this information and $e = 13$, find the secret key $d$. Use the Extended Euclidean Algorithm from page 30 of the slides. Show all steps in your computation.

6. Why is a cryptographically secure hash function used in connection with RSA digital signatures?

7. With RSA, why would you never use the value 2 as one of of the two primes $p$ and $q$?

8. In RSA, why must the message being encrypted be a non-negative integer strictly less than the modulus?

9. Consider an RSA system with Alice's public key $N = 1517$ and $e = 17$. Note that $1517 = 37 \cdot 41$.

   (a) Find Alice's secret key $d$. As described on page 29 of the slides, you should use the Extended Euclidean Algorithm (page 30 of the slides).

   (b) Try encrypting 423. Use the algorithm for fast modular exponentiation (page 27 on the slides). How many times during the recursive execution is the "**if** $k$ is odd" case encountered, and how many times is the "**if** $k$ is even" case encountered? [Do not include the base cases $k = 0$ and $k = 1$ in the counts.]

   (c) Decrypt the number obtained above, using fast modular exponentiation. Is the result correct? How many times during the recursive execution is the "if k is odd" case encountered, and how many times is the "if k is even" case encountered? [Do not include the base cases k = 0 and k = 1 in the counts.]

## II: Løses hjemme inden øvelsestimerne i uge 48

1. Why in RSA is it necessary that $gcd(e, (p-1)(q-1)) = 1$? Find an example (that is, find values $e$, $p$ and $q$) where this greatest common divisor is not equal to 1.

2. Find four different square roots of 1 modulo 143, i.e., numbers which multiplied by themselves modulo 143 give 1 (and which are at least 0 and less than 143). You may consider writing a simple program for finding them.

3. Try executing the Miller-Rabin primality test on 11, 15, and 561. First, what type of numbers are they (note: 561 is known from the slides)? For each, run the Miller-Rabin test by hand for at least one value $a$ of your own choice, preferably for more, using Python for the individual calculations (raising to a power and first then using modulus should work in reasonable time for numbers this size, hence there is no need to use the fast modular exponentiation algorithm in this exercise). Which calculations showed that the composite numbers were not prime—the first line (the Fermat test) or later lines?

   With 561, be sure to try an $a$ relatively prime to 561 (most are, 2 is a simple example used in the slides, 4, 5, 7, 10, and 13 are other examples). What happens differently if you try $a = 3$? Can you explain the latter?