Assignment 0x03

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January 6, 2018

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1 Explain why the integers Z form a ring, and the rationals Q form a field.

1.1 Definition: ring

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2 Task 1: Number Theory and Algebra

2.1 Explain why the integers Z form a ring, and the rationals Q form a field.

A ring is a set R with two operations "+" and "*". (R,+) is an abelian group, that means it is associative, commutative and has a neutral and inverse element. (R,*) is a monoid, that means it is associative and has a neutral element. Lastly multiplication is distributive with respect to addition. If all axioms hold, a set is a ring. And they hold for Z.

A field is a ring but with the special case that (R
{0}, *) is an abelian group. Meaning that associativity and commutativity hold for all elements except 0 and that there also exists a neutral and inverse element for every element of the field.

2.2 Find the inverses of all elements in $\mathbf{Z_7}^*$. Why do all numbers between 1 and 6 have an inverse?

$Z_7^* = 1, 2, 3, 4, 5, 6$

A number is an inverse, if number mod inverse = 1 (the neutral element)

Number:	1	2	3	4	5	6
Inverse:	1	4	5	2	3	6

If n is a prime, then all numbers between 1 and n-1 have an inverse with the modulo-Operation. This is due to n not being a multiple of any of the elements in the set.

2.3 As an exercise, calculate the inverse of 331 in $\mathbf{Z_{1234}}$ using the extended euclidean algorithm.

GCD = 1, if Rest is 0 in the end

$1234 == 3 * 331 + 241$

$331 == 1 * 241 + 90$

$241 == 2 * 90 + 61$

$90 == 1 * 61 + 29$

$61 == 2 * 29 + 3$

$29 == 9 * 3 + 2$
$3 == 1 * 2 + 1$
$2 == 2 * 1 + 0$

Applying the algorithm:
$1 == 3 - 1 * 2$
$1 == 3 - (29 - 9 * 3)$
$1 == 10 * 3 - 1 * 29$
$1 == 10 * (61 - 2 * 29) - 1 * 29$
$1 == 10 * 61 - 21 * 29$
$1 == 10 * 61 - 21 * (90 - 1 * 61)$
$1 == 31 * 61 - 21 * 90$
$1 == 31 * (241 - 2 * 90) - 21 * 90$
$1 == 31 * 241 - 83 * 90$
$1 == 31 * 241 - 83 * (331 - 241 * 1)$
$1 == 114 * 241 - 83 * 331$
$1 == 114 * (1234 - 3 * 331) - 83 * 331$
$1 == 114 * 1234 - 425 * 331$

Inverse of 331 is -425. Since it is not in Z we add 1234 to it until it is: $-425 + 1234 = 809 => 809$ is the inverse of 331 in canonical form.

Test: $331 * 809 = 267779$
$267779\%1234 = 1$
So the calculations are correct.

2.4 Find all generators of Z_{11}

	1	2	3	4	5	6	7	8	9	10	
1	1	1	1	1	1	1	1	1	1	1	
2	2	4	8	5	10	9	7	3	6	1	TRUE
3	3	9	5	4	1	3	9	5	4	1	FALSE
4	4	5	9	3	1	4	5	9	3	1	FALSE
5	5	3	4	9	1	5	3	4	9	1	FALSE
6	6	3	7	9	10	5	8	4	2	1	TRUE
7	7	5	2	3	10	4	6	9	8	1	TRUE
8	8	9	6	4	10	3	2	5	7	1	TRUE
9	9	4	3	5	1	9	4	3	5	1	FALSE
10	10	1	10	1	10	1	10	1	10	1	TRUE

ExcelFormula = MOD((linke Spalteˆ Obere Zeile);11)
The marked lines (2, 6, 7, 8) are generators.

2.5 Calculate 42^{497} in Z_{1361} using fast exponentiation and a handheld calculator (not the one running on your computer or a programming language). Document a, e and n for each step.

Fastexp(a=42, n=497)
1st Iteration:

e = 1
n is odd:
e = (42 * 1) mod 1361 = 42
a = 42 mod 1361 = 1764 mod 1361 = 403
n = 497 / 2 = 248

2):

e = 42
n is even:
a = 403 mod 1361 = 450
n = n/2 = 124

3)

e = 42
n is even:
a = 450 mod 1361 = 1072
n = 124 / 2 = 62

4)

e = 42
n is even:
a = 1072 mod 1361 = 500
n = 62 /2 = 31

5)

e = 42
n is odd:
e = (500 * 42) mod 1361 = 585
a = 500 mod 1361 = 937
n = 31 / 2 = 15

6)
e = 1072
n is odd:
e = (937 * 585) mod 1361 = 1023
a = 937 mod 1361 = 124
n = 15 / 2 = 7

7)

e = 46
n is odd:
e = (124 * 1023) mod 1361 = 279
a = 124 mod 1361 = 405
n = 7 / 2 = 3

8)

e = 260
n is odd:
e = (405*279) mod 1361 = 32
a = 405 mod 1361 = 705
n = 3 / 2 = 1

9)

e = 503
n is odd:
e = (705*32) mod 1361 = 784
a = 705 mod 1361 = 260
n = 1 / 2 = 0

10)

$n = 0$ => return e = 784

=> 42497 mod 1361 = 784
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2.6 Definition: field

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3 Task 2: The RSA cryptosystem

3.1 Using that private key, decrypt c

$PHI(n) = (p-1)(q-1) = (17-1)*(23-1) = 16*22 = 352$

$e = 17; Z^*_{352}$
(e * d) mod 352 = 1

Using Excel we found the inverse using the formula above: d = 145

m = c^d mod n = 282^{145} mod 391 = 197

3.2 Did Donald choose reasonable parameters? Explain!

When e = 1, the message itself is encrypted just by applying the modulo with the public Key part N. Resulting in c = m mod N, which means that if m is smaller than N, the encrypted message is just the plain message => c = m

3.3 Find a value of e for which RSA encryption is the identity function