Foundations of Computer Algebra. CS424b: Quiz 3. UWO, March 30, 2005.

Student ID number:
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Guidelines. Every printed document is allowed but computers and calculators are not. The duration of the quiz is 40 minutes. The quiz consists of three exercises located on pages 2, 4, 8. All answers should be written in the *answer boxes*. No justifications for the answers are needed, unless explicitly required. You are expected to do this quiz on your own without assistance from anyone else in the class. If possible, please avoid pencils and use pens with dark ink. Thank you.

Notations. The set of non-negative integer numbers, integer numbers and rational numbers are denoted respectively $\mathbb{N}$, $\mathbb{Z}$ and $\mathbb{Q}$, as usual. For an integer $n \in \mathbb{Z}$ the set of the multiples of n (all of them: positive, null or negative) is denoted by $n\mathbb{Z}$. For an integer $n \in \mathbb{Z}$ the residue class ring of the binary relation $(a, b) \longmapsto a \equiv b \mod n$ is denoted by $\mathbb{Z}/n\mathbb{Z}$, as usual. For a ring $\mathbb{A}$, we denote by $\mathbb{A}[x]$ the ring of univariate polynomials in x with coefficients in $\mathbb{A}$.

Formulas. We give the mutiplication table of $\mathbb{Z}/17\mathbb{Z}$.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	4	6	8	10	12	14	16	1	3	5	7	9	11	13	15
3	6	9	12	15	1	4	7	10	13	16	2	5	8	11	14
4	8	12	16	3	7	11	15	2	6	10	14	1	5	9	13
5	10	15	3	8	13	1	6	11	16	4	9	14	2	7	12
6	12	1	7	13	2	8	14	3	9	15	4	10	16	5	11
7	14	4	11	1	8	15	5	12	2	9	16	6	13	3	10
8	16	7	15	6	14	5	13	4	12	3	11	2	10	1	9
9	1	10	2	11	3	12	4	13	5	14	6	15	7	16	8
10	3	13	6	16	9	2	12	5	15	8	1	11	4	14	7
11	5	16	10	4	15	9	3	14	8	2	13	7	1	12	6
12	7	2	14	9	4	16	11	6	1	13	8	3	15	10	5
13	9	5	1	14	10	6	2	15	11	7	3	16	12	8	4
14	11	8	5	2	16	13	10	7	4	1	15	12	9	6	3
15	13	11	9	7	5	3	1	16	14	12	10	8	6	4	2
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

Exercise 1. In this exercise, detailed and precise explanations are required. As expected, we consider the field $\mathbb{K} = \mathbb{Z}/17\mathbb{Z}$.

1. Show that 3 is in $\mathbb{K}$ a primitive 16-th root of unity.
2. Find all primitive 4-th roots of unity in $\mathbb{K}$.

Answer 1

Answer 2

Exercise 2. In the ring $\mathbb{A} = \mathbb{K}[x]$ of univariate polynomials with coefficients in $\mathbb{K} = \mathbb{Z}/17\mathbb{Z}$, we consider the polynomials $f_1 = x^2 + 1$, $g_1 = x + 1$, $f_2 = x^3 + x^2 + x + 1$ and $g_2 = x^2 + 3x + 1$. Using one of the FFT-based multiplication algorithms described in the course notes:

1. compute the product of the polynomials f_1 and g_1
2. compute the product of the polynomials f_2 and g_2

For each product, you should give (at least) the results of each *Discrete Fourier Transforms*. Of course, you should better choose primitive roots of unity that minize the number of required operations in $\mathbb{K}$.

Answer 3

Answer 4

Answer 5

Answer 6

Exercise 3. Explain how one could use the FFT-based polynomial multiplication techniques in order to compute the product of two polynomials $f, g \in \mathbb{Z}[x]$ with degree less than n. Several approaches are possible. You are asked to describe at least one. (Note that one is given in the course notes.) Suggesting another approach would add a bonus of 5 points.

Answer 7