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Estimation of Range of Appearance in Heptadecagonal Numbers

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Abstract: In this document, the range of appearance $I(r)$ of a positive integer r in heptagonal numbers and some results by comparing $I(r)$ with Legendre symbol, p – adic range and prime conjunction function of r are accessible. Since $I(r)$ does not possess a meticulous prototype, all the results are confirmed by Java program for all-natural numbers $r \in \mathbb{N}$.

Keywords: Heptadecagonal number, range of appearance, p – adic range

I. INTRODUCTION

“In 1796, an arithmeticians Gauss showed that a regular polygon of 17 sides can be created using a scale and compass by screening that a primitive 17th root of unity can be found by solving a succession of quadratic equations over the rationals. A heptadecagram is a star polygon with 17-sides.

The sequence of Heptadecagonal number is provoked by $H(m) = \frac{m(15m-13)}{2}$, $m \in \mathbb{N}$ [1-4]. Many prominent arithmeticians have apportioned with concepts of divisibility of Fibonacci numbers. In [5], the author pondered the equation $Z(n) = (2 - \frac{1}{K})n$ involving order of appearance in Fibonacci numbers. In this framework, one may grasp [6-10]. In this document, the range of appearance $I(r)$ of $r \in \mathbb{N}$ in the pattern of heptagonal numbers and few results by measure up to $I(r)$ with Legendre symbol, p – adic range and prime conjunction functions are offered. Since $I(r)$ does not have a particular model, each and every result are entrenched by Java program for all values of $r \in \mathbb{N}$.

1) Definition

“A quadratic residue modulo n is an integer t such that it is congruent to square of a number. That is there can exists an integer Y such that $Y^2 \equiv t \pmod{n}$ ” [1].

2) Definition

In [2], The Legendre symbol is a number hypothetical function $\left(\frac{r}{p}\right)$ which is defined by

$$\left(\frac{r}{p}\right) = \begin{cases} 0, & \text{if } \frac{p}{r} \\ 1, & \text{if } r \text{ is a quadratic residue modulo } p \\ -1, & \text{if } r \text{ is a quadratic nonresidue modulo } p \end{cases}$$

3) Definition

“The greater power of a prime number p which divides a positive integer r is called p – adic range of r and it is symbolized by $d_p(r)$ ”.

4) Definition

“The prime conjunction function of a positive integer r is the separate prime factors of r and it is designated by $\Lambda(r)$ ”.

5) Definition

“The range of appearance of a positive integer r in the sequence of Heptadecagonal numbers signified by $I(r)$ is defined as the lowest natural number m such that $r|H(m)$ ” [5].

The values of $I(r)$ for discrete values of r such that $1 \leq r \leq 20$ are listed in the table below.

r	1	2	3	4	5	6	7	8	9	10	11	12
$I(r)$	1	3	3	3	5	3	6	3	9	15	6	3
r	13	14	15	16	17	18	19	20	21	22	23	24
$I(r)$	13	7	15	3	2	27	11	35	6	11	7	3
r	25	26	27	28	29	30	31	32	33	34	35	36
$I(r)$	25	39	27	27	26	15	5	35	6	19	20	27
r	37	38	39	40	41	42	43	44	45	46	47	48
$I(r)$	28	11	39	35	20	27	41	11	45	7	4	3
r	49	50	51	52	53	54	55	56	57	58	59	60
$I(r)$	27	75	36	91	15	27	50	35	30	55	52	75
r	61	62	63	64	65	66	67	68	69	70	71	72
$I(r)$	9	31	27	35	65	39	50	19	30	20	34	99
r	73	74	75	76	77	78	79	80	81	82	83	84
$I(r)$	69	28	75	11	3	39	43	35	81	20	23	27
r	85	86	87	88	89	90	91	92	93	94	95	96
$I(r)$	70	43	84	83	78	135	13	99	36	4	30	99
r	97	98	99	100								
$I(r)$	72	27	72	75								

The range of appearance of a positive integer r in the already mentioned sequence of Heptadecagonal numbers for all other choices of $r \in N$ are found out by the following Java program.

```
import java.util.Scanner;
import java.util.ArrayList; // import the ArrayList class
import java.util.Collections; // import Collections
class Main {
public static void main(String[] args) {
Scanner myObj = new Scanner(System.in); // Create a Scanner object
System.out.println("Enter the value of m:");
String m = myObj.nextLine(); // Read user input
int x = Integer.parseInt(m);
ArrayList < Integer > result = findM(x);
System.out.println(result);
System.out.println("Enter the value of r:");
String r = myObj.nextLine(); // Read user input
int y = Integer.parseInt(r);
ArrayList < Integer > resultN = findN(y);
System.out.println(resultN); }
//set values to m,r and temp as arraylist
// array list will help to have elements of any size.
static ArrayList < Integer > tmNet = new ArrayList < Integer > ();
static ArrayList < Integer > tnNet = new ArrayList < Integer > ();
static ArrayList < Integer > tmp = new ArrayList < Integer > ();
static int m;
static int r;
```

```

static int tm;
static int result = 0;
static ArrayList < Integer > findM(int val){
m = val;
for(int i = 1; i <= m; i ++){
result = i * ((15 * i) - 13)/2;
tmNet.add(result);
} return tmNet; //return m
} static ArrayList < Integer > findN(int val){
r = val;
for(int j = 1; j <= r; j ++){
for(int i = 1; i <= r; i ++){
tm = i * ((15 * i) - 13)/2;
int val2 = (int) Math.round(tm/j);
if (val2 != 0 && tm%j == 0){ //take value divisible by iterator and the value is > 0
tmp.add(i);
}}
if(!tmp.isEmpty()){
tnNet.add(Collections.min(tmp)); //take min val from list
tmp.removeAll(tmp); //reset array to every iteration
}}
return tnNet; //return r
}}

```

II. ESTIMATION OF RANGE OF APPEARANCE IN HEPTADECAGONAL NUMBERS:

Some results based on the range of appearance of a positive integer r in the above held sequence of Heptadecagonal numbers for numerous selections of a natural number r are explored and are verified by Java program.

A. Result 1

Let n be a positive integer of the form $r = p^x$, where p is a prime number.

- i. If $p = 2$, then $I(2^x) \leq 3 \cdot (2^{x-1})$, for $x \geq 1$.
- ii. If $p = 3$, then $I(3^x) \leq 3^x$, for $x \geq 1$.
- iii. If $p = 5$, then $I(5^x) \leq 5^x$, for $x \geq 1$.
- iv. If $p > 5$, then $I(p^x) \leq \left(p - \left(\frac{2}{p}\right)\right) \cdot p^{x-1}$, for $x \geq 1$ where $\left(\frac{r}{p}\right)$ is a legendre symbol

Java program for monitoring this result is specified below.

```

import java.util.Scanner;
import java.util.ArrayList; // import the ArrayList class
import java.util.Collections; // import Collections
import java.lang.Math;
import java.util.*;
class Main {
public static void main(String[] args) {
Scanner myObj = new Scanner(System.in); // Create a Scanner object
System.out.println("Enter the value of r:");
String r = myObj.nextLine(); // Read user input
int y = Integer.parseInt(r);
ArrayList < Integer > resultN = findN(y);
System.out.println("r: " + getRepValues());
}
}

```

```

System.out.println("I(r) " + resultN); }
//set values to m,r and temp as arraylist
// array list will help to have elements of any size.
static ArrayList < Integer > tnNet = new ArrayList < Integer > ();
static ArrayList < Integer > tmp = new ArrayList < Integer > ();
static int m; static int r; static int tm;
static int result = 0;
static ArrayList < Integer > rep = new ArrayList < Integer > ();
static ArrayList < Integer > findN(int val){
r = val;
for(int j = 1; j ≤ r; j++){
for(int i = 1; i ≤ r; i++){
tm = i * ((15 * i) - 13)/2;
int val2 = (int) Math.round(tm/j);
if (val2 != 0 && tm%j == 0 && j%2 == 0 && (int)(Math.ceil((Math.log(j) / Math.log(2)))) ==
(int)(Math.floor(((Math.log(j) / Math.log(2))))))){ //take value divisible by iterator and the value is
> 0, is divisible by 2 and is also power of 2.
rep.add(j);
tmp.add(i); }}
if(!tmp.isEmpty()){
tnNet.add(Collections.min(tmp)); //take min val from list
tmp.removeAll(tmp); //reset array to every iteration
}} return tnNet; //return r
} static ArrayList < Integer > getRepValues(){
Set < Integer > unique_ = new HashSet <> (rep);
rep.clear();
rep.addAll(unique_);
return rep; }}

```

B. Result 2

Let r be an even integer and $d_2(r)$, $\wedge(r)$ are 2 – adic range of r and the prime conjunction function of r respectively.

i. If $d_2(r) = 1$, then

$$I(r) \leq \begin{cases} 2r, & \text{if } \wedge(r) = 2 \text{ and } r \nmid 5 \\ \frac{4r}{3}, & \text{if } \wedge(r) = 2 \text{ and } r \nmid 5 \\ 2 \left(\frac{5}{2}\right)^{\wedge(r)-\mathfrak{S}_r-2} r, & \text{if } \wedge(r) > 2 \end{cases}$$

ii. If $d_2(r) = 2$, then

$$I(r) \leq \begin{cases} \frac{3r}{2}, & \text{if } \wedge(r) = 2 \text{ and } r \nmid 5 \\ \frac{7r}{6}, & \text{if } \wedge(r) = 2 \text{ and } r \nmid 5 \\ 3 \left(\frac{1}{2}\right)^{\wedge(r)-\mathfrak{S}_r-2} r, & \text{if } \wedge(r) > 2 \end{cases}$$

iii. If $d_2(r) = 3$, then

$$I(r) \leq \begin{cases} \frac{5r}{2}, & \text{if } \wedge(r) = 2 \text{ and } r \nmid 5 \\ \frac{4r}{3}, & \text{if } \wedge(r) = 2 \text{ and } r \nmid 5 \\ 2 \left(\frac{1}{2}\right)^{\wedge(r)-\mathfrak{S}_r-2} r, & \text{if } \wedge(r) > 2 \end{cases}$$

iv. If $d_2(r) \geq 4, \wedge(r) = 2$, then $I(r) \leq \frac{7}{4} \left(\frac{2}{3}\right)^{\wedge(r)-\mathfrak{S}_r-1} r$, where $\mathfrak{S}_r = \begin{cases} 0 & \text{if } r \nmid 5 \\ 1 & \text{if } r \mid 5 \end{cases}$

Java program for checking all the above four statements are laid down below.

```
import java.util.Scanner;
import java.util.ArrayList; // import the ArrayList class
import java.util.Collections; // import Collections
import java.lang.Math;
import java.util.*;
class Main {
public static void main(String[] args) {
Scanner myObj = new Scanner(System.in); // Create a Scanner object
System.out.println("Enter the value of p:");
String r = myObj.nextLine(); // Read user input
int y = Integer.parseInt(r);
boolean flag = false;
for (int i = 2; i <= y / 2; ++i) { // condition for nonprime number
if (y % i == 0) {
flag = true; break; }
}
if (!flag) {
int param = (int) Math.round(Math.pow(2, 4) * y);
System.out.println(y + " is a prime number.");
ArrayList < Integer > resultN = findN(param);
System.out.println("r: " + getRepValues());
System.out.println("I(r) " + resultN);
} else {
System.out.println(y + " is not a prime number. Please rerun the program and enter a prime number !!");
} // set values to m, n and temp as arraylist
// array list will help to have elements of any size.
static ArrayList < Integer > tnNet = new ArrayList < Integer > ();
static ArrayList < Integer > tmp = new ArrayList < Integer > ();
static ArrayList < Integer > finalresult = new ArrayList < Integer > ();
static int m;
static int r;
static double tm;
static int result = 0;
static ArrayList < Integer > rep = new ArrayList < Integer > ();
static ArrayList < Integer > findN(int val) {
r = val;
for (int j = 1; j <= r; ++j) {
for (int i = 1; i <= r; ++i) {
tm = i * ((15 * i) - 13) / 2;
int val2 = (int) Math.round(tm / r);
if (val2 != 0 && tm % r == 0) { // take value divisible by iterator and the value is > 0 and is integer value
rep.add(r); // n is a constant here so we add the calculated
tmp.add(i); //
}
}
if (!tmp.isEmpty()) {
tnNet.add(Collections.min(tmp)); // take min val from list
tmp.removeAll(tmp); // reset array to every iteration
}
}
if (!tnNet.isEmpty()) {
finalresult.add(Collections.min(tnNet)); // tnNet; // return r
}
```

```
}return finalresult;  
}static ArrayList < Integer > getRepValues(){  
Set < Integer > unique_ = new HashSet <> (rep);  
rep.clear();rep.addAll(unique_);  
return rep;}}
```

III. CONCLUSION

In this paper, the range of appearance $I(r)$ of a positive integer r in heptagonal numbers is defined and limited number of results consisting $I(r)$, legendre symbol, p – adic range and prime conjunction function of r are evaluated. Entire results are inveterate by Java program for all positive values of r . In this approach, one can define the range of appearance of an integer in other polygonal numbers and may analyse their results by comparing the values of $I(r)$ with Jacobi symbol, quadratic residue and non-residue modulo r .

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