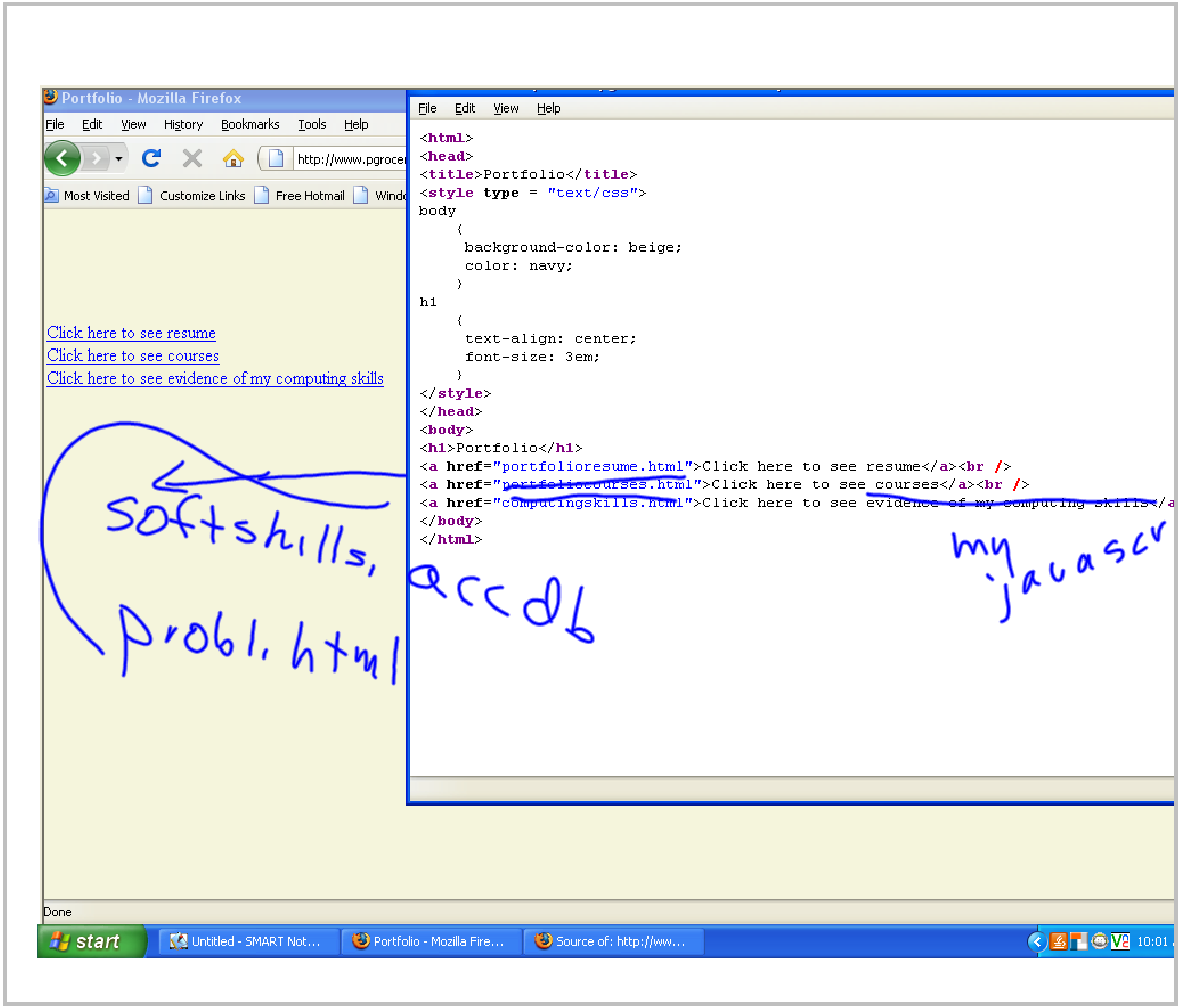

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Decimal — base 10   10 digits 0-9

face value

2	6	7	3_{10}
10^3	10^2	10^1	10^0
1000	100	10	1

(position row: 10^3, 10^2, 10^1, 10^0)

2

20

$$2 \times 10^3 = 2 \times 1000 = 2000$$
$$6 \times 10^2 = 6 \times 100 = 600$$
$$7 \times 10^1 = 7 \times 10 = 70$$
$$3 \times 10^0 = 3 \times 1 = 3$$

$$= 2673$$

Binary base 2   2 digits 0, 1

100 → $1 \times 2^2 = 1 \times 4 = 4$

$0 \times 2^1 = 0 \times 2 = 0$

$1 \times 2^0 = 0 \times 1 = 0$

4

1 0

2^3 2^2 2^1 2^0

8 4 2 1   positional values

$1 \times 2^1 = 1 \times 2 = 2$

$0 \times 2^0 = 0 \times 1 = 0$

2

Dec	Bin
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

		1	0
2^3	2^2	2^1	2^0
		2	1

	1	0	0
2^3	2^2	2^1	2^0
8	4	2	1

1	0	0	0	0
2^4	2^3	2^2	2^1	2^0
16	8	4	2	1

$1+1=10$

```
   10
 +  1
 ----
   11
 +  1
 ----
  100
 +  1
 ----
  101
```

$10101_2 = \underline{21}_{10}$

face

	1	0	1	0	1
	2^4	2^3	2^2	2^1	2^0
pos	16	8	4	2	1

$1 \times 2^4 = 1 \times 16 = 16$

$0 \times 2^3 = 0 \times 8 = 0$

$1 \times 2^2 = 1 \times 4 = 4$

$0 \times 2^1 = 0 \times 2 = 0$

$1 \times 2^0 = 1 \times 1 = 1$

21_{10}

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http://www.pgrocer.net/Cis17/notes/numbers.html

5724

Binary Numbering systems:
The binary numbering system works much the same way as the decimal numbering system except that now we are in base 2 so we only have 2 digits (0, 1). The value of the number is still determined by the face value times the positional value, but since we are in base 2, the positional values are the powers of 2. Since the face values can only be 0 or 1, this means that the 0 or 1 is multiplied by the positional place in which it is found.
Example: binary number 1011011

1	0	1	1	0	1	1	Face value
2^6	2^5	2^4	2^3	2^2	2^1	2^0	Positional value
64	32	16	8	4	2	1	Resolved positional value

The positional values are first shown in the powers of 2 and then as the resolved number - in other words, 2 to the 6th is equal to 64.

Converting binary to decimal:
In the previous example to find the decimal equivalent for the number 1011011, we do the following:

$1 \times 2^6 = 1 \times 64 =$	64
$0 \times 2^5 = 0 \times 32 =$	0
$1 \times 2^4 = 1 \times 16 =$	16
$1 \times 2^3 = 1 \times 8 =$	8
$0 \times 2^2 = 0 \times 4 =$	0
$1 \times 2^1 = 1 \times 2 =$	2
$1 \times 2^0 = 1 \times 1 =$	1
	91

Converting decimal to binary:
Before doing this it is important that we review the decimal equivalent for the frequently used powers of 2:

$1010110_2 = \underline{\quad 86 \quad}_{10}$

1	0	1	0	1	1	0
2^6	2^5	2^4	2^3	2^2	2^1	2^0
64	32	16	8	4	2	1

$86_{10} = \_\_\_\_\_\_\_\_\_\_\_\__2$

1	0	1	0	1	1	0

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

$$\begin{array}{r} 86 \\ -64 \\ \hline 22 \end{array}$$

$22 - 16 = 6 - 4 = 2 - 2 = 0$

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Converting decimal to binary:

Before doing this it is important that we review the decimal equivalent for the frequently used powers of 2:

$2^0 = 1$ $2^1 = 2$ $2^2 = 4$ $2^3 = 8$ $2^4 = 16$ $2^5 = 32$

$2^6 = 64$ $2^7 = 128$ $2^8 = 256$ $2^9 = 512$ $2^{10} = 1024$ etc.

To convert 91 from decimal to binary, you can follow the following steps:

1. Look at 91 and see what power of 2 can be taken from it. The highest power that can be subtracted is 2 to the 6th which is 64. Therefore we put a 1 in the 2 to the 6th position. Then we subtract: 91 - 64 = 27

1	____	____	____	____	____	____
2^6	2^5	2^4	2^3	2^2	2^1	2^0
64	32	16	8	4	2	1

2. Now we look at what is left, 27 and see if the next power of 2 (moving to the right) which is 2 to the 5th or 32 can be subtracted from 27. It can't, therefore we didn't use the 2 to the 5th position so we put a 0 in the 2 to the 5th position. Since we didn't use the 32, there is no subtraction.

1	0	____	____	____	____	____
2^6	2^5	2^4	2^3	2^2	2^1	2^0
64	32	16	8	4	2	1

3. Now we check to see if the next power of 2 (moving to the right) which is 2 to the 4th with the value of 16 can be subtracted from 27. It can, therefore we put a 1 in the 2 to the 4th position. Then we subtract: 27 - 16 = 11.

1	0	1	____	____	____	____
2^6	2^5	2^4	2^3	2^2	2^1	2^0
64	32	16	8	4	2	1

4. Now, we look at the next power of 2 which is 2 to the 3rd which resolves to 8 and check to see if 8 can be subtracted from 11. It can, therefore we put a 1 in the 2 to the 3rd position. Then we subtract 11 - 8 = 3

1 0 1 1

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Now, we are going to learn to count in binary and relate counting in binary to counting in decimal. 0 and 1 are the same values in binary and decimal but then we come to add 1 to 1 and we discover that there is no 2 in binary. Essentially we have run out of digits. We stop and think what we do in decimal when we run out of digits and we get the pattern to use in binary. For example, in decimal when we try to add 1 to 9, we run out of digits.

In decimal:	9	In binary:	1
	+1		+1
	10		10

What we find is that when we run out of digits, we simply go to the next position - we call this putting down the 0 and carrying the 1.

Continuing along:

10	11	100	101	110	111	1000
+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1
11	100	101	110	111	1000	1001

This means that when we count, we get the following:

Decimal	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000

Done

$$\begin{array}{r} {}^{1}\ \ {}^{1} \\ 1\,1\,0\,1\,1_2 = 27_{10} \\ +\,1\,0\,0\,1\,0 = 18_{10} \\ \hline 1\,0\,1\,1\,0\,1 \end{array}$$

32 16 8 4 2 1 → 45_{10}

$$\begin{array}{r} 1 \\ +1 \\ \hline 10 \end{array}$$

1	1	0	1	1
2^4	2^3	2^2	2^1	2^0
16	8	4	2	1
1	0	0	1	0

10 10 1

$1101 = 13$

111

$$
\begin{array}{r}
1110 \\
+1010 \\
\hline
101100
\end{array}
\qquad
\begin{array}{r}
14 \\
10 \\
\hline
44_{10}
\end{array}
$$

32 16 8 4 2 1

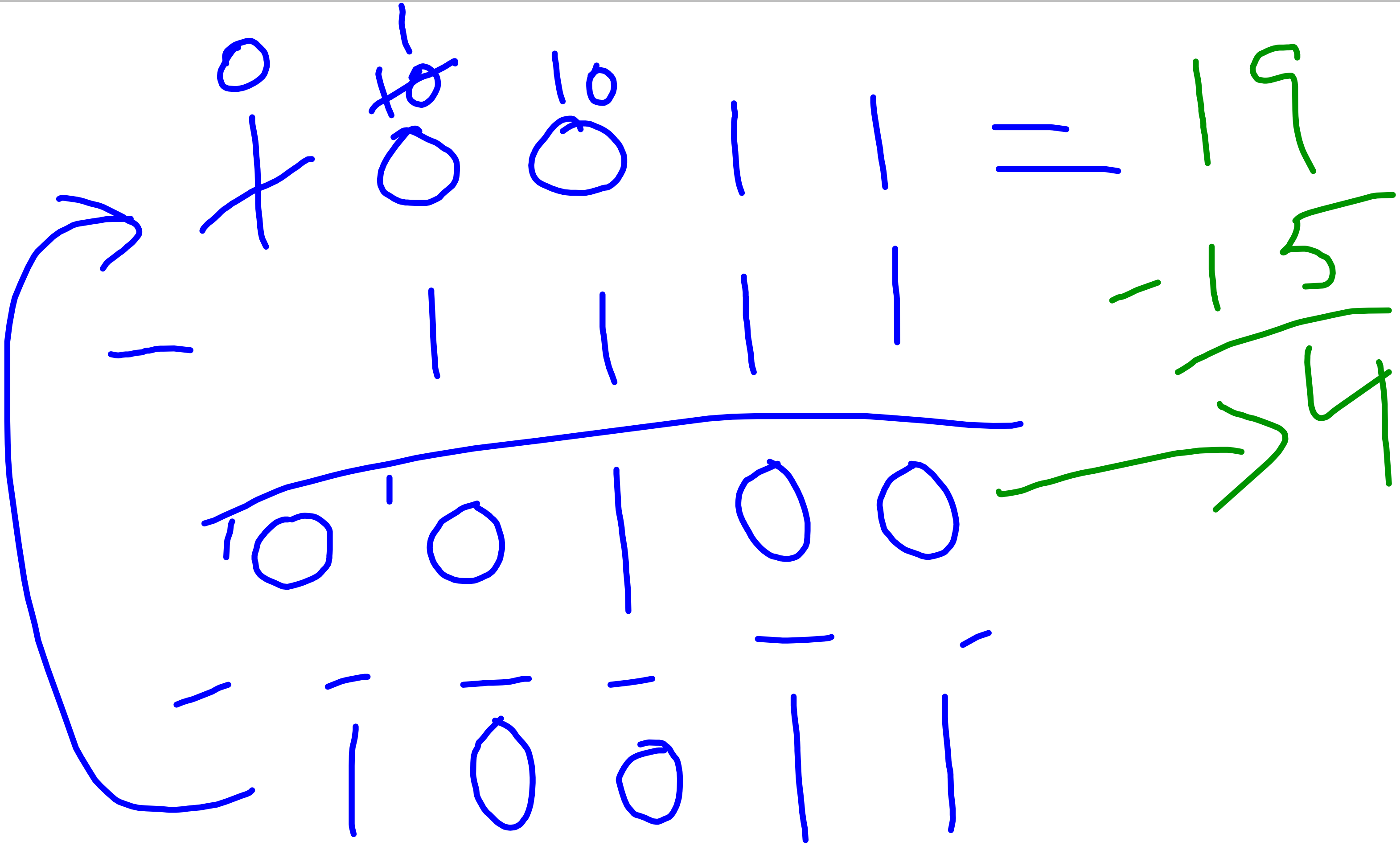
101100

$$
\begin{array}{r}
1 \\
+\ 1 \\
\hline
10 \\
+\ 1 \\
\hline
11 \\
+\ 1 \\
\hline
100 \\
+\ 1 \\
\hline
101
\end{array}
$$

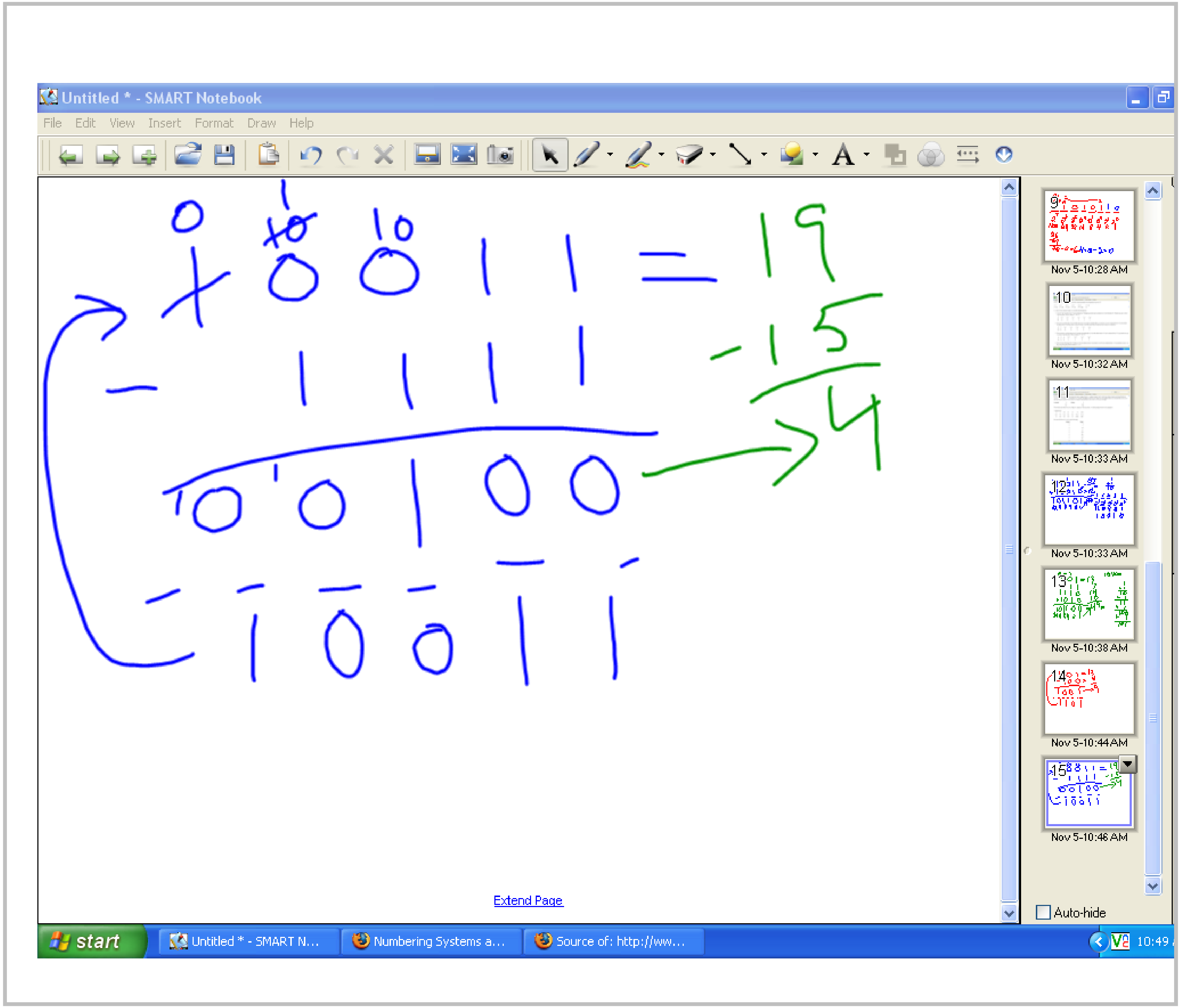
1101 = 13
− 100 = 4

1001 → 9

1101



1 0 0 1 1 = 19
- 1 1 1 1
0 0 1 0 0
- 1 0 0 1 1
-15
4



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