BinaryNotes
09 1

AP CS Principles   Binary Supplement

"A ______________, or binary digit, is the smallest unit of information processed by a computer and consists of a single zero or one. A ___________ consists of 8 adjacent bits."

"The transistor, the basic building block of the CPU and RAM, is a simple device that can in one of two states – ON, conducting electricity, or OFF, not conducting electricity. All the information in a computer – programs and data – is expressed in terms of these ONs and OFFs, 1s and 0s, as they are more conveniently called."

n bits can be used to represent _________ different values.□*** see extension notes. Therefore 8 bits represent ____ values and 16 bits represent ____ values.

Java uses _____ bytes to represent an int and therefore can store ___________ different values: ____.

A double is _____ bytes long. 1 bit is used for the sign, 52 bits for the coefficient, and 11 bits for the exponent.

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In base 10, the number 5403 can be expressed as: $5 * 10^3 + 4 * 10^2 + 0 * 10^1 + 3 * 10^0$

NOTE: 5000+ 400 + 0 + 3 = 5403. We sum the value of each position in base 10. (and other bases as well!)

The right-most digit tells you how many ones you have; the next digit tells you how many tens you have and so on. The same concept can be applied to numbers expressed in other bases. For example, convert the following values to base 10.

374_8 is equal to ____ $* 8^3$ + ___ $* 8^2$ + ___ $* 8^1$ + ___ $* 8^0$ = ___________ in base 10

1101_2 is equal to ____ * ____^{3} + ____ * ____^{2} + ____ * ____^{1} + ____ * ____^{0} = ___________ in base 10

53_9 is equal to ____ * ____^{3} + ____ * ____^{2} + ____ * ____^{1} + ____ * ____^{0} = ___________ in base 10

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Backtrack on notes at each math concept.

n bits can be used to represent _____ values? Hmmm lets see. . .
If each place can be only 2 different things, a one or a zero

1 place:	1	0	2 values	_____
2 places:	1 1 0 1	1 0 0 0	4 values	_____
3 places:	1 1 1 1 1 0 0 1 1 0 1 0	1 0 1 1 0 0 0 0 1 0 0 0	8 values	_____
4 places:			16 values	_____
n places:				_____

Also look at base 10 numbers:

what digits do we have for base 10?
_____ thru _____ inclusive (meaning includes both ends)

what digits do we have for base 2? ?
_____ thru _____ inclusive (meaning includes both ends)

soooo what digits do we have for base 3?
? _____ thru _____ inclusive (meaning includes both ends)

what digits do we have for base 4?
? _____ thru _____ inclusive (meaning includes both ends)

what digits do we have for base n?
? _____ thru _____ inclusive (meaning includes both ends)

extension:
how many values can be represented by base 3 with 2 places? _____
what is the range of values? _______________

how many values can be represented by base 3 with 3 places? _____
what is the range of values? _______________

how many values can be represented by base 3 with n places? _____
what is the range of values? _______________

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☆'s by what you must Know.... Binary!

AP Computer Science
Unit 2. Exercises

A common standard is 24-bit color where 8 bits are used to represent the amount of red light, 8 bits for green light, and 8 bits for blue light. It is the combination of these three colors that generates every other color you see on a monitor.

go back to binary notes!

1. How many different levels of red can be represented using 8 bits? ________________
2. How many different colors can be represented using 24 bits? ____________________

Y2K refers to a computer problem from the previous century. In the early days of computers, memory (whether for storage or running a program) was very expensive. So, when recording dates, only the last two digits were saved. For example, the year 1985 would be saved as 85. This worked well enough for most programs at first but with the approach of the year 2000, it needed to be fixed; otherwise the year 2000 would be indistinguishable from the year 1900 (as both would be saved as 00).

3. How many bits are necessary to save a number from 0 to 99? ________________
4. How many bits are necessary to save a number from 0 to 9999? ________________

5. An Arduino Uno microcontroller can detect a voltage between 0 and 5 volts. How many bits does it use to represent the voltage if 1023 indicates 5 volts and 0 indicates 0 volts? __________

in other words if 1023 is largest number....

Translate each binary number into a base ten number.

☆

6)	1010_2	7)	$0010\ 0001_2$
8)	1111_2	9)	$1000\ 0000_2$
10)	$1111\ 1111_2$	11)	$1000\ 1000_2$

Translate each hexadecimal number into a base ten number

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12)	31_{16}	13)	$2F_{16}$
14)	$5D_{16}$	15)	$A5_{16}$
16)	59_{16}	17)	12_{16}

Numbers written to base 16 are hexadecimal numbers and the following letters are used to represent different values: A = 10, B = 11, C = 12, D = 13, E, = 14, F = 15

$2F_{16}$ is equal to _____ $* 16^3 +$ ___ $* 16^2 +$ ___ $* 16^1 +$ ___ $* 16^0 =$ ____________ in base 10

you expand the hex number below to change it into base 10

$A4_{16}$ is equal to ____ * ____ + ____ * _____ + ____ * ____ = ____________ in base 10

Here is one way to convert a number from base 10 to another base. To demonstrate this approach, let's say that we want to convert 70 base 10 to base 4. NOTE: this is more difficult.
First, construct a table with enough columns so that the leftmost column represents a number larger than the number you are converting. Beneath each base ^ exponent, write the equivalent value in non-exponential form. Finally, in the bottom row write out how many of each you need to represent your target. In the table below, you need one 64, one 4, and two ones to represent the number 70.

Exponents	4^4	4^3	4^2	4^1	4^0
Value base 10	256	64	16	4	1
To represent 70 you will need					

Therefore, $70_{10} = 1012_4$□ 70/64 = 1 70 – 64 = 6 6/16 = 0 6/4 = 1 6 – 4 = 2

To convert 440 base 10 to hex ...

Therefore, 440_{10} =□

Exponents	16^3	16^2	16^1	16^0
Value base 10	4096	256	16	1
To represent 440 you will need	0	1	11	8

Therefore, 440_{10} = __________ 16□

440 / 4096 = 0 440/256 = 1 440 – 256 = 184
184/16 = 11 (B) 184 – (16)(11) = 8

To convert 5175 base 10 to hexadecimal

Exponents	$\_\_\_^{3}$	$\_\_\_^{2}$	$\_\_\_^{1}$	$\_\_\_^{0}$
Value hexadecimal				
To represent 5175 you will need				

Later we will translate numbers from base 2 to hex and hex to base 2. We will translate numbers from base 4 to base 8 and even add numbers in different bases. We will practice our base system understanding over the next several days and continue to revisit this throughout the year. It is a good skill for a computer scientist.

$42_5 \rightarrow \_\_\_\__{10}$

$17_{10} \rightarrow \_\_\_\__{2}$

$53_{10} \rightarrow \_\_\_\__{7}$

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Translate each number into a base 10 number. If a number is incorrectly represented, and therefore cannot be translated, write INVALID.

18) 22_3	19) 80_7
20) 31_5	21) 123_4
22) 272_8	23) 55_6

Translate each base ten integer into a binary number.

24) 67	25) 100
26) 8	27) 12
28) 50	29) 88

Translate each base ten number into a hexadecimal number.

30) 30	31) 123
32) 8	33) 64
34) 54	35) 75

36) Convert this integer from base 10 to base 5

24 ______________________

37) Convert this integer from base 10 to base 9

18 ______________________

38) Convert this integer from base 10 to base 7

60 ______________________

39) Convert this integer from base 10 to base 3

23 ______________________

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Name ______________

Switching between Base 2 and any other base that is a multiple of 2

Lets start with the traditional base 2 to base 16 (hexadecimal)

Using base 2 (only 1s and 0s) how many digits or places would you need to represent a hex digit? Well hex numbers are base 16 and therefore can represent the digits from 0 through 15 (remember that 10 is A, 11 is B, etc). To represent 0 through 15 using base 2 or binary you need 4 places:

0 0 0 0 = 0 $\quad 0 * 2^3 + 0 * 2^2 + 0 * 2^1 + 0 * 2^0$

1 1 1 1 = 15 $\quad 1 * 2^3 + 1 * 2^2 + 1 * 2^1 + 1 * 2^0 \quad 8 + 4 + 2 + 1 = 15$

What this means is that for every 4 digits in base 2 we can group them together to make one hexadecimal digit! Check it out below:

0010/1010/0011 == 2/10/3 == $2A3_{16}$ (10 is A in hex)

Proof, convert each number to decimal:

Binary 0010 1010 0011 = $1 * 2^9 + 1 * 2^7 + 1 * 2^5 + 1 * 2^1 + 1 * 2^0$
= 512 + 128 + 32 + 2 + 1 = 675

Hex 0010 1010 0011 = $2 * 16^2 + A * 16^1 + 3 * 16^0$
= 512 + 160 + 3 = 675

Now you try converting between base 2 and hexadecimal or base 16:

$0110\ 1110\ 1010_2$ == ______________ $_{hex}$

$10\ 1111\ 0110\ 0010_2$ == ______________ $_{hex}$

Try the backside for more practice:

BASE COMPARISON using quick change method

Binary	> < or =	Hexadecimal
11011100	>	75
10101011		AB
101101		2F
1011000		58
11001000		B2
01011110		5E
10110001		B2
1010		14
1100100		62
1111101000		3DD
001111011101		3D3
1010001110		28E
111110100		226
1011000		66
10100111		A7
10		10
00010001		11

CHALLENGE QUESTIONS:

Can you change this base 2 number to base 8 using learning from above?

$101101110001_2 =$ ______________ $_8$

Can you change this base 4 number to base 2 using learning from above?

$3021_4 =$ ____________________ $_2$

RGB to HEX

RGB to HEX Conversion Worksheet:

Convert the following Hex values to RGB Decimal Values:

1. AC0BFF ________________
2. 11AACB ________________
3. FFCC00 ________________
4. 660099 ________________
5. FFFFFF________________ (What color is this?)
6. 000000 ________________ (What color is this?)
7. BCABFF ________________
8. 99FFA1 ________________
9. AFBCA5________________
10. 667AFB ________________

Convert the following Decimal RGB values to Hex values

1. (255,100,87) ________________
2. (109,0,124) ________________
3. (86,10,91) ________________
4. (255,255,255) ______________ (What color is this?)
5. (0,0,0) ________________(What color is this?)
6. (102,101,77)________________
7. (10,18,122) ________________
8. (134,29,37) ________________
9. (57,123,48)________________
10. (255,18,73)________________

RGB to HEX Conversion Worksheet: KEY

Convert the following Hex values to RGB Decimal Values:

1. AC0BFF *172,11,255*
2. 11AACB *17, 170, 203*
3. FFCC00 *255,204,0*
4. 660099 *102,0,153*
5. FFFFFF *255,255,255* (What color is this?) *White*
6. 000000 *0,0,0* (What color is this?) *Black*
7. BCABFF *188,171,255*
8. 99FFA1 *153, 255, 161*
9. AFBCA5 *175,188,165*
10. 667AFB *102,122,251*

Convert the following Decimal RGB values to Hex values

1. (255,100,87) *FF6457*
2. (109,0,124) *6D007C*
3. (86,10,91) *560A5B*
4. (255,255,255) *FFFFFF* (What color is this?) *White*
5. (0,0,0) *000000* (What color is this?) *Black*
6. (102,101,77) *66654D*
7. (10,18,122) *0A127A*
8. (134,29,37) *861D25*
9. (57,123,48) *397B30*
10. (255,18,73) *FF1249*