



GRACE Education Curriculum Satellites	
Teachers	Grades 6-8
<b>Math</b>	

## DECODING GRACE

**Background Information:** Satellites, such as the Global Positioning System (GPS) and GRACE (Gravity Recovery and Climate Experiment), send and receive encoded signals as their method of communication. Many satellites and computers use systems that send raw data using binary codes. To understand binary numbers, begin by recalling elementary school math. When we first learned about numbers, we were taught that, in the decimal system, things are organized into columns:

H | T | O  
1 | 9 | 3

such that "H" is the hundreds column, "T" is the tens column, and "O" is the ones column. So the number "193" is 1-hundreds plus 9-tens plus 3-ones.

The binary system works under the exact same principles as the decimal system, only it operates in base 2 rather than base 10. In other words, instead of columns being  $10^2|10^1|10^0$  they are  $2^2|2^1|2^0$

Instead of using the digits 0-9, we only use 0-1 (again, if we used anything larger it would be like multiplying  $2 \cdot 2^n$  and getting  $2^{n+1}$ , which would not fit in the  $2^n$  column. Therefore, it would shift you one column to the left. For example, "3" in binary cannot be put into one column. The first column we fill is the right-most column, which is  $2^0$ , or 1. Since  $3 > 1$ , we need to use an extra column to the left, and indicate it as "11" in binary ( $1 \cdot 2^1 + 1 \cdot 2^0$ ).

Please note that the number of digits in any base (*radix*) N is exactly the same number N. For example, in the binary ( $N = 2$ ) system there are two digits: 0 and 1; in the decimal ( $N = 10$ ) there are ten of them: 0,1,2,3,4,5,6,7,8,9.

Computers use binary code. So that we can store words, we can assign a unique byte to each Latin character. In the following table, the first column is, of course, the letter. The second column is the decimal representation assigned to the letter. Finally, the third column is the binary representation of the letter.

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a	97	01100001	n	110	01101110
b	98	01100010	o	111	01101111
c	99	01100011	p	112	01110000
d	100	01100100	q	113	01110001
e	101	01100101	r	114	01110010
f	102	01100110	s	115	01110011
g	103	01100111	t	116	01110100
h	104	01101000	u	117	01110101
i	105	01101001	v	118	01110110
j	106	01101010	w	119	01110111
k	107	01101011	x	120	01111000
l	108	01101100	y	121	01111001
m	109	01101101	z	122	01111010

This designation is a part of the standard for converting text to binary called **ASCII** (or ASCII code). Of course there are many more letters and symbols we have only listed the lower case letters here. **ASCII** stands for:

A = American

S = Standard

C = Code for

I = Information

I = Interchange

ASCII is used to convert all of the characters you type into binary information so the computer can understand it. Here is the **binary representation** of phrase – “**math teacher link**”, a space is 32 or 00100000):

01101101 0110001 01110100 01101000 0010000 01110100 01100101 01100001 01100011  
 01101000 01100101 01110010 0010000 01101100 01101001 01101110 01101011

Besides accurately storing information binary information is easy for machines to manipulate and perform operations on and with.

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**Objectives:** Through their work in the binary system, students will develop an understanding and an appreciation of the way data is encoded and sent from satellites to computers on the Earth

**Standards:** Math: number and operations; understanding numbers; ways of representing numbers; relationships among numbers; and number systems  
Science: science as inquiry; science and technology

**Vocabulary:** binary ASCII

**Materials:** paper writing tools

**Directions to the Teacher:**

After explaining binary numbers to the students, conduct the following activity:

1. Divide students in the class in cooperative groups.
2. Each group should write a sentence, which relates to the GRACE satellite. For example, "GRACE measures the Earth's gravity field."
3. Assign each letter to its position number in the alphabet.

A=1	F=6	K=11	P=16	U=21	Z=26
B=2	G=7	L=12	Q=17	V=22	
C=3	H=8	M=13	R=18	W=23	
D=4	I=9	N=14	S=19	X=24	
E=5	J=10	O=15	T=20	Y=25	

Write the sentence by position numbers.

G-7 R-18 A-1 C-3 E-5  
m-13 e-5 a-1 s-19 u-21 r-18 e-5 s-19  
t-20 h-8 e-5  
E-5 a-1 r-18 t-20 h-8 s-19  
g-7 r-18 a-1 v-22 I-9 t-20 y-25  
f-6 I-9 e-5 l-12 d-4

4. Write the numbers from 1-26 in base 2.

Convert base 10 (GRACE message) numerals to base 2. Be sure to indicate spaces or slashes between the words.

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5. Each group will send one scout to someone else's group with their message, and each group will receive a message from another group.
  6. Decode the message your group received.
  7. Send a scout back to the group that sent your group the message, after you've decoded it. Is it correct?

**Extensions:**

Write your name in binary using the ASCII code.

Choose another base and send a message in that base. To make it more challenging, don't tell the receiving group what base the sending group used.

Interview a computer programmer to discuss other computer languages.

**References / Resources:**

<http://www.edbydesign.com/btcount.html>

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