

1. a) What is the largest binary number that can be expressed with 14 bits? b) What are the equivalent decimal and hexadecimal numbers?

a) $(11111111111111)_2$

b) $(1 \times 2^{13}) + (1 \times 2^{12}) + (1 \times 2^{11}) + (1 \times 2^{10}) + (1 \times 2^9) + (1 \times 2^8) + (1 \times 2^7) + (1 \times 2^6) + (1 \times 2^5) + (1 \times 2^4) + (1 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) = 16383$

$(16383)_{10}$

0011	1111	1111	1111
3	15	15	15
	↓	↓	↓
	F	F	F

$(3FFF)_{16}$

2. Convert 421 to binary in two ways. Convert directly to binary; convert to hexadecimal and then to binary.

① $(421)_{10} \Rightarrow (?)_2$

	Result	Remainder	
$2 \overline{)421}$	210.5	1	↑
$2 \overline{)210}$	105	0	
$2 \overline{)105}$	52.5	1	
$2 \overline{)52}$	26	0	
$2 \overline{)26}$	13	0	
$2 \overline{)13}$	6.5	1	
$2 \overline{)6}$	3	0	
$2 \overline{)3}$	1.5	1	
$2 \overline{)1}$	0.5	1	

$$(110100101)_2$$

2. ② $(421)_{10} \Rightarrow (?)_{16}$

	Result	Remainder	↑
$(16) \overline{) 421}$	26.3125	5	1
$16 \overline{) 26}$	1.625	10	1
$16 \overline{) 1}$	0.0625	1	1

$(1A5)_{16}$

$(1A5)_{16} \Rightarrow (?)_2$

0	0	0	1	1	0	1	0	0	1	0	1
8	4	2	1	8	4	2	1	8	4	2	1

$(110100101)_2$

3. Express the following numbers in decimal. a) 10111.0111_2

b) 26.24_8

c) $BAFA_{16}$

$$a) (10111.0111)_2 \Rightarrow (?)_{10}$$

$$(1 \times 2^4) + (1 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) + (1 \times 2^{-2}) + (1 \times 2^{-3}) + (1 \times 2^{-4}) = 23.4375$$

$$\boxed{(23.4375)_{10}}$$

$$b) (26.24)_8 \Rightarrow (?)_{10}$$

$$(2 \times 8^1) + (6 \times 8^0) + (2 \times 8^{-1}) + (4 \times 8^{-2})$$

$$= \boxed{(22.3125)_{10}}$$

$$c) (BAFA)_{16} \Rightarrow (?)_{10}$$

$$(16^3 \times 11) + (16^2 \times 10) + (16^1 \times 15) + (16^0 \times 10)$$

$$= \boxed{(47866)_{10}}$$

4. Convert the following numbers to binary: a) 28.315 b) $2/3$

a) $(28.315)_{10} \Rightarrow (?)_2$

	Result	Remainder	
$2 \overline{) 28}$	14	0	↑
$2 \overline{) 14}$	7	0	
$2 \overline{) 7}$	3.5	1	
$2 \overline{) 3}$	1.5	1	
$2 \overline{) 1}$	0.5	1	

11100

$$\begin{array}{r} 0.315 \\ \times 2 \\ \hline 0.630 \end{array}$$

$w_1 = 0$

$$\begin{array}{r} 0.63 \\ \times 2 \\ \hline 1.26 \end{array}$$

$w_2 = 1$

$$\begin{array}{r} 0.26 \\ \times 2 \\ \hline 0.52 \end{array}$$

$w_3 = 0$

$(11100.010)_2$

4. b) $(2/3)_{10} \Rightarrow (?)_2$

$$\begin{array}{r} 0.667 \\ \times \quad 2 \\ \hline 1.334 \end{array} \quad w_1 = 1$$

$$\begin{array}{r} 0.334 \\ \times \quad 2 \\ \hline 0.668 \end{array} \quad w_2 = 0$$

$$\begin{array}{r} 0.668 \\ \times \quad 2 \\ \hline 1.336 \end{array} \quad w_3 = 1$$

$$\begin{array}{r} 0.336 \\ \times \quad 2 \\ \hline 0.672 \end{array} \quad w_4 = 0$$

$$\boxed{(0.1010)_2}$$

$0 \rightarrow 1$
 $1 \rightarrow 0$

1's complement + 1

5.

Original	1's Complement	2's Complement
10000011	01111100	01111101
00000000	11111111	100000000
11011011	00100100	00100101
01110110	10001001	10001010
10000101	01111010	01111011
11111111	00000000	00000001

$\begin{array}{r} 11111111 \\ 11111111 \\ + \quad 1 \\ \hline 100000000 \end{array}$

6.	Decimal	Binary	Hexadecimal	Octal
a)	444	110111100	1BC	674
b)	46030	1011001111001110	B3CE	131716
c)	N/A	N/A	N/A	3872
d)	39673	100110101111001	9AF9	115371
e)	4321	1000011100001	10E1	10341
f)	4779	1001010101011	12AB	11253
g)	1708	11010101100	6AC	3254
h)	23061	0101101000010101	5A15	55025

a) $(444)_{10}$

$$\begin{array}{cccccccccc} 256 & 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ (1 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0) \end{array} \Bigg|_2$$

$$\begin{array}{ccc} \boxed{0001} & \boxed{1011} & \boxed{1100} \\ 1 & 11 & 12 \end{array} \Rightarrow (1BC)_{16}$$

$$\begin{array}{ccc} \boxed{110} & \boxed{111} & \boxed{100} \\ 6 & 7 & 4 \end{array} \Rightarrow (674)_8$$

$$b) (B3CE)_{16}$$

$$\begin{array}{cccc} \begin{array}{|c|c|c|} \hline 11 \\ \hline 1011 \\ \hline \end{array} & \begin{array}{|c|c|c|} \hline 3 \\ \hline 0011 \\ \hline \end{array} & \begin{array}{|c|c|c|} \hline 12 \\ \hline 1100 \\ \hline \end{array} & \begin{array}{|c|c|c|} \hline 14 \\ \hline 1110 \\ \hline \end{array} \Rightarrow (1011001111001110)_2 \end{array}$$

$$\begin{array}{cccccc} \begin{array}{|c|c|c|} \hline 001 \\ \hline 1 \\ \hline \end{array} & \begin{array}{|c|c|} \hline 011 \\ \hline 3 \\ \hline \end{array} & \begin{array}{|c|c|} \hline 001 \\ \hline 1 \\ \hline \end{array} & \begin{array}{|c|c|} \hline 111 \\ \hline 7 \\ \hline \end{array} & \begin{array}{|c|c|} \hline 001 \\ \hline 1 \\ \hline \end{array} & \begin{array}{|c|c|} \hline 110 \\ \hline 6 \\ \hline \end{array} \Rightarrow (131716)_8 \end{array}$$

$$(16^0 \times 14) + (16^1 \times 12) + (16^2 \times 3) + (16^3 \times 11) = (46030)_{10}$$

$$c) (3872)_8$$

An [↑]octal can not have 8 as a digit. Octal numbers are only 0-7. Therefore, I can not convert this number.

$$d) (1001\ 1010\ 1111\ 1001)_2$$

$$(2^0 \times 1) + (2^3 \times 1) + (2^4 \times 1) + (2^5 \times 1) + (2^6 \times 1) + (2^7 \times 1) + (2^8 \times 1) + (2^{11} \times 1) + (2^{12} \times 1) + (2^{15} \times 1) = (39673)_{10}$$

$$\begin{array}{cccc} \begin{array}{|c|c|c|} \hline 1001 \\ \hline 9 \\ \hline \end{array} & \begin{array}{|c|c|c|} \hline 1010 \\ \hline 10 \\ \hline \end{array} & \begin{array}{|c|c|c|} \hline 1111 \\ \hline 15 \\ \hline \end{array} & \begin{array}{|c|c|c|} \hline 1001 \\ \hline 9 \\ \hline \end{array} \Rightarrow (9AF9)_{16} \end{array}$$

$$\begin{array}{cccccc} \begin{array}{|c|c|c|} \hline 001 \\ \hline 1 \\ \hline \end{array} & \begin{array}{|c|c|} \hline 001 \\ \hline 1 \\ \hline \end{array} & \begin{array}{|c|c|} \hline 101 \\ \hline 5 \\ \hline \end{array} & \begin{array}{|c|c|} \hline 011 \\ \hline 3 \\ \hline \end{array} & \begin{array}{|c|c|} \hline 111 \\ \hline 7 \\ \hline \end{array} & \begin{array}{|c|c|} \hline 001 \\ \hline 1 \\ \hline \end{array} \Rightarrow (115371)_8 \end{array}$$

e) $(4321)_{10}$

$$\begin{array}{cccccccccccccccc} 4096 & 2048 & 1024 & 512 & 256 & 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ (& 1 & & 0 & & 0 & & 0 & & 0 & & 1 & & 1 & & 1 & & 0 & & 0 & & 0 & & 0 & & 1 &)_2 \end{array}$$

$$\begin{array}{cccc} \begin{array}{|c|} \hline 0001 \\ \hline 1 \end{array} & \begin{array}{|c|} \hline 0000 \\ \hline 0 \end{array} & \begin{array}{|c|} \hline 1110 \\ \hline 14 \end{array} & \begin{array}{|c|} \hline 0001 \\ \hline 1 \end{array} \end{array} \Rightarrow (10E1)_{16}$$

$$\begin{array}{ccccc} \begin{array}{|c|} \hline 001 \\ \hline 1 \end{array} & \begin{array}{|c|} \hline 000 \\ \hline 0 \end{array} & \begin{array}{|c|} \hline 011 \\ \hline 3 \end{array} & \begin{array}{|c|} \hline 100 \\ \hline 4 \end{array} & \begin{array}{|c|} \hline 001 \\ \hline 1 \end{array} \end{array} \Rightarrow (10341)_8$$

f) $(12AB)_{16}$

$$(16^0 \times 11) + (16^1 \times 10) + (16^2 \times 2) + (16^3 \times 1) = (4779)_{10}$$

$$\begin{array}{cccc} \begin{array}{|c|} \hline 1 \\ \hline 0001 \end{array} & \begin{array}{|c|} \hline 2 \\ \hline 0010 \end{array} & \begin{array}{|c|} \hline 10 \\ \hline 1010 \end{array} & \begin{array}{|c|} \hline 11 \\ \hline 1011 \end{array} \end{array} \Rightarrow (1001010101011)_2$$

$$\begin{array}{ccccc} \begin{array}{|c|} \hline 001 \\ \hline 1 \end{array} & \begin{array}{|c|} \hline 001 \\ \hline 1 \end{array} & \begin{array}{|c|} \hline 010 \\ \hline 2 \end{array} & \begin{array}{|c|} \hline 101 \\ \hline 5 \end{array} & \begin{array}{|c|} \hline 011 \\ \hline 3 \end{array} \end{array} \Rightarrow (11253)_8$$

$$g) (3254)_8$$

$$(8^0 \times 4) + (8^1 \times 5) + (8^2 \times 2) + (8^3 \times 3) = (1708)_{10}$$

$$\begin{array}{cccc} 3 & 2 & 5 & 4 \\ \underline{0} & \underline{1} & \underline{1} & \underline{0} & \underline{1} & \underline{0} & \underline{1} & \underline{0} & \underline{0} \end{array} \Rightarrow (11010101100)_2$$

$$\begin{array}{|c|} \hline 0110 \\ \hline 6 \\ \hline \end{array} \quad \begin{array}{|c|} \hline 1010 \\ \hline 10 \\ \hline \end{array} \quad \begin{array}{|c|} \hline 1100 \\ \hline 12 \\ \hline \end{array} \Rightarrow (6AC)_{16}$$

$$h) (0101101000010101)_2$$

$$(2^0 + 2^2 + 2^4 + 2^9 + 2^{11} + 2^{12} + 2^{14}) = (23061)_{10}$$

$$\begin{array}{|c|} \hline 0101 \\ \hline 5 \\ \hline \end{array} \quad \begin{array}{|c|} \hline 1010 \\ \hline 10 \\ \hline \end{array} \quad \begin{array}{|c|} \hline 0001 \\ \hline 1 \\ \hline \end{array} \quad \begin{array}{|c|} \hline 0101 \\ \hline 5 \\ \hline \end{array} \Rightarrow (5A15)_{16}$$

$$\begin{array}{|c|} \hline 101 \\ \hline 5 \\ \hline \end{array} \quad \begin{array}{|c|} \hline 101 \\ \hline 5 \\ \hline \end{array} \quad \begin{array}{|c|} \hline 000 \\ \hline 0 \\ \hline \end{array} \quad \begin{array}{|c|} \hline 010 \\ \hline 2 \\ \hline \end{array} \quad \begin{array}{|c|} \hline 101 \\ \hline 5 \\ \hline \end{array} \Rightarrow (55025)_8$$

7. Perform the indicated operations:

$$\begin{array}{r} \overset{1}{A} \overset{1}{B} C D_{16} \\ + 1234_{16} \\ \hline 18E01_{16} \end{array}$$

$$\begin{array}{r} \overset{1}{3} \overset{1}{7} 70_8 \\ + 1234_8 \\ \hline 5224_8 \end{array}$$

$$\begin{array}{r} \overset{1}{1} \overset{1}{0} \overset{1}{0} \overset{1}{1} 1011011_2 \\ + 11011000100_2 \\ \hline 101110011111_2 \end{array}$$

$$\begin{array}{r} \overset{0}{1} \overset{10}{X} \overset{0}{0} \overset{10}{1} \overset{0}{0} \overset{10}{1} \overset{0}{0} 111_2 \\ - 00110100111_2 \\ \hline 10100110100_2 \end{array}$$

$$\begin{array}{r} 1011_2 \\ \times 1101_2 \\ \hline 111011 \\ 00000 \\ 11101100 \\ + 1011000 \\ \hline 10001111_2 \end{array}$$

8. Complete the table for the following 8-bit numbers signed magnitude numbers

	Decimal	2's Complement
a)	+25	0001 1001
b)	-11	1111 0101
c)	-103	1001 1001
d)	-105	1001 0111
e)	-20	1110 1100
f)	86	0101 0110

$$a) +25 \Rightarrow \begin{array}{cccccccc} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \end{array}$$

$$b) -11 \Rightarrow \begin{array}{cccccccc} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \end{array}$$



$$\begin{array}{r} (11110100)_{1s} \\ + \\ \hline (11110101)_{2s} \end{array}$$

$$c) -103 \Rightarrow \begin{array}{cccccccc} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 1 \end{array}$$



$$\begin{array}{r} (10011000)_{1s} \\ + \\ \hline (10011001)_{2s} \end{array}$$

$$d) (1001\ 0111)_{25}$$

$$- \quad (1001\ 0110)_{15}$$

$$\Downarrow$$

$$(0110\ 1001)_2$$

$$\begin{array}{cccccccc} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 \end{array} \Rightarrow 64 + 32 + 8 + 1 = 105$$

$$(-105)_{10}$$

$$e) (1110\ 1\cancel{0}\cancel{0}\cancel{0})_{25}$$

$$- \quad (1110\ 1011)_{15}$$

$$\Downarrow$$

$$(0001\ 0100)_2$$

$$\begin{array}{cccccccc} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \end{array} \Rightarrow 16 + 4 = 20$$

$$(-20)_{10}$$

$$f) (0101\ 0110)_{25}$$

$$\begin{array}{cccccccc} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 & 1 & 0 \end{array} \Rightarrow 64 + 16 + 4 + 2 = 86$$

$$(86)_{10}$$

9. Perform subtraction on the following unsigned binary numbers using 2's complement. If the results are negative, 2's complement the result and affix a minus sign.

a) $10011 - 10011$

$$\begin{array}{r} 01100 \\ + \quad 1 \\ \hline (01101)_{2c} \end{array} \quad \begin{array}{r} 11111 \\ 10011 \\ + 01101 \\ \hline \cancel{1}00000 \end{array} \quad \boxed{+(00000)}$$

b) $100010 - 100011$

$$\begin{array}{r} 011100 \\ + \quad 1 \\ \hline 011101 \end{array} \quad \begin{array}{r} 100010 \\ + 011101 \\ \hline 111111 \end{array} \quad \begin{array}{r} 000000 \\ + \quad 1 \\ \hline 000001 \end{array} \quad \boxed{-(000001)}$$

c) $1001 - 101001$

$$\begin{array}{r} 010110 \\ + \quad 1 \\ \hline 010111 \end{array} \quad \begin{array}{r} 11111 \\ 001001 \\ + 010111 \\ \hline 100000 \end{array} \quad \begin{array}{r} 11111 \\ 011111 \\ + \quad 1 \\ \hline 100000 \end{array} \quad \boxed{-(100000)}$$

d) $110000 - 10111 \Rightarrow 110000 - 010111$

$$\begin{array}{r} 101000 \\ + \quad 1 \\ \hline 101001 \end{array} \quad \begin{array}{r} 110000 \\ + 101001 \\ \hline \cancel{1}011001 \end{array} \quad \boxed{+(011001)}$$

10. Convert 8823 to BCD and ASCII, respectively

8	8	2	3
<u>1</u>	<u>0</u>	<u>0</u>	<u>0</u>
<u>0</u>	<u>1</u>	<u>0</u>	<u>0</u>
<u>0</u>	<u>0</u>	<u>0</u>	<u>1</u>
<u>0</u>	<u>0</u>	<u>1</u>	<u>0</u>
<u>0</u>	<u>0</u>	<u>0</u>	<u>1</u>
<u>1</u>	<u>1</u>	<u>0</u>	<u>1</u>

$(8823)_{10} \Rightarrow (1000100000100011)_{BCD}$