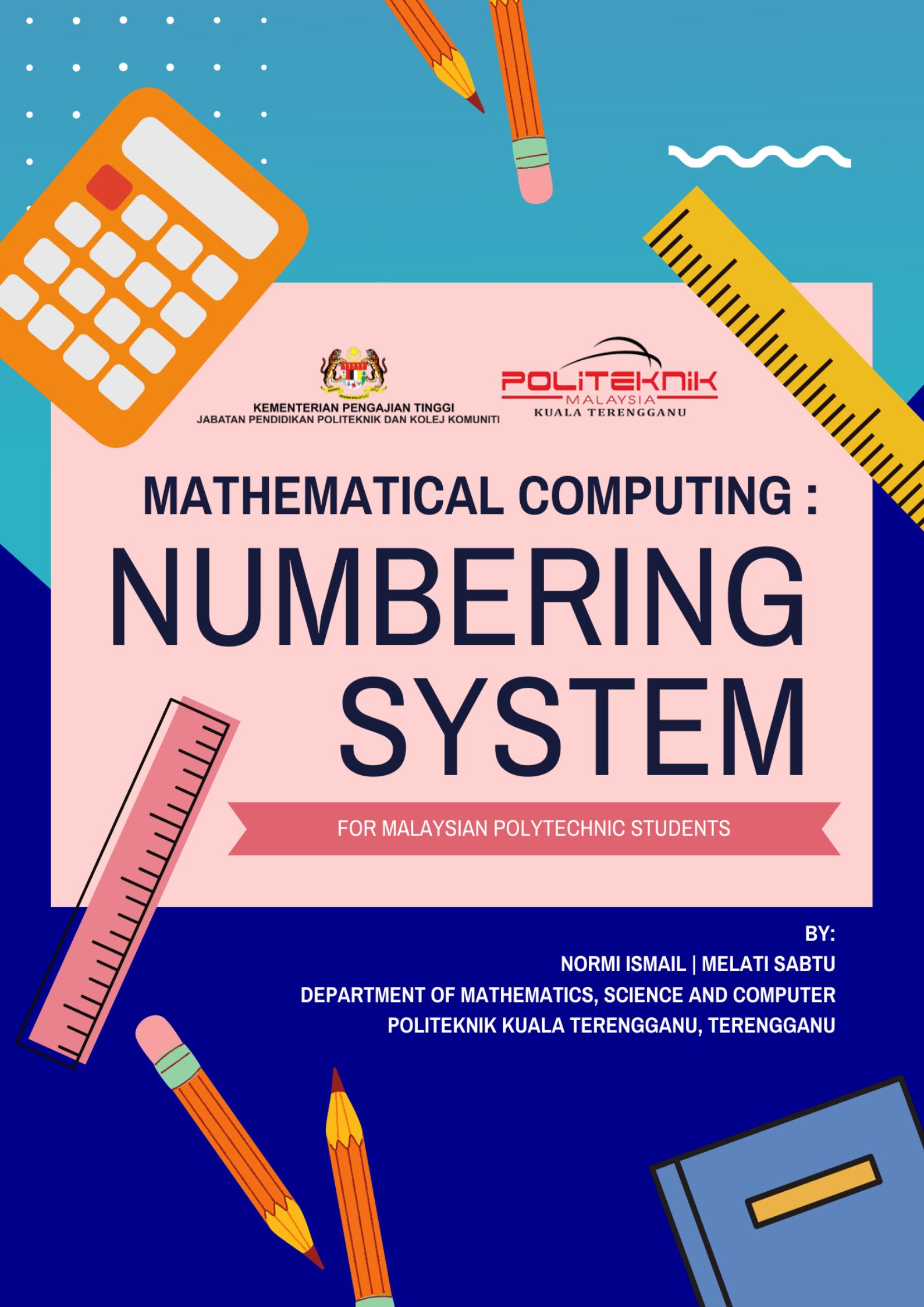

KEMENTERIAN PENGAJIAN TINGGI
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

POLITEKNIK MALAYSIA
KUALA TERENGGANU

MATHEMATICAL COMPUTING :
NUMBERING SYSTEM

FOR MALAYSIAN POLYTECHNIC STUDENTS

BY:
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By:

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ABSTRACT

MATHEMATICAL COMPUTING: NUMBERING SYSTEM FOR MALAYSIAN POLYTECHNIC STUDENTS

This book introduces students to numbering system, octal numbering system, hexadecimal numbering system and binary arithmetic. This book emphasizes the binary, octal and hexadecimal numbering systems used in computer science and computer programming. It introduces the way numbers are represented in each of these systems, how to switch between them (and to and from base 10).

Therefore, this book contains FIVE (5) main chapters, various examples of work and tutorials to enhance students learning abilities. The authors hope this book can provide useful resources to students and lecturers.

This book is the full property of Politeknik Kuala Terengganu which is used on the online / offline learning platform. The production of this book is also suitable for use by community college, pre-diploma and university students.

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NUMBERING SYSTEM

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1.6 Data Organization
Bits, Nibbles, Bytes, Words and Double Words

1.7 Unit, Number, Base/Radix, Positional Notation and Most & Least Significant Digits

NUMBERING SYSTEM

Numbering system is a way or system representing numbers by using digits or other symbols in a consistent manner. The numbers allow us to operate arithmetic operations such as addition, subtraction, and multiplication.

1.1 DECIMAL, BINARY, OCTAL AND HEXADECIMAL

There are **four (4) main different types of number systems** which are decimal, binary, octal and hexadecimal.

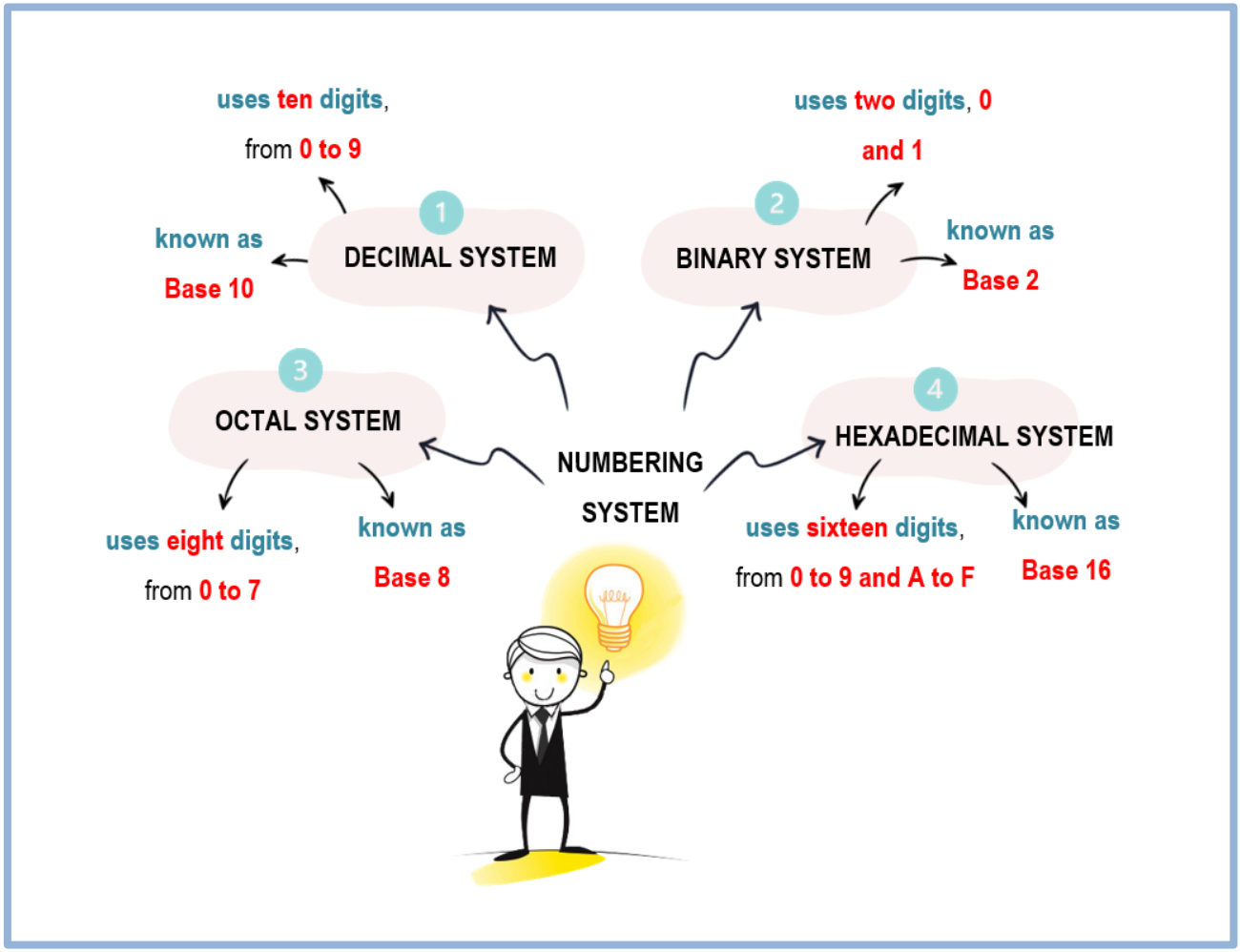
1. **Decimal System** | A numbering system that **uses ten (10) digits**, from 0 to 9, arranged in a series of columns to represent all numerical quantities. Each column or place value has a weighted value of 1, 10, 100, 1000, and so on, ranging from right to left. Since this system uses ten (10) digits, it has the **Base 10.**

2. **Binary System** | A numbering system that **uses two (2) digits**, 0 and 1, arranged in a series of columns to represent all numerical quantities. Each column or place value has a weighted value of 1, 2, 4, 8, 16, and so on, ranging from right to left. Since this system uses two (2) digits, it has the **Base 2**.

3. **Octal System** | A numbering system that **uses eight (8) digits**, 0 to 7, arranged in a series of columns to represent all numerical quantities. Each column or place value has a weighted value of 1, 8, 64, 512, and so on, ranging from right to left. Since this system uses eight (8) digits, it has the **Base 8**.

4. **Hexadecimal System** | A numbering system that **uses sixteen (16) digits**, 0 to 9 and A to F, arranged in a series of columns to represent all numerical quantities. Each column or place value has a weighted value of 1, 16, 256, 4096, and so on, ranging from right to left. Since this system has sixteen (16) alphanumeric values, it has the **Base 16**.

MIND MAP: NUMBERING SYSTEM



1.2 DIFFERENT TYPES OF NUMBER SYSTEMS

SYSTEM	BASE	ALLOWED DIGITS	USED BY
Decimal	10	0, 1, 2, 3, 4, 5, 6, 7, 8, 9	Human
Binary	2	0, 1	Computer
Octal	8	0, 1, 2, 3, 4, 5, 6, 7	Computer
Hexadecimal	16	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F	Computer

Quantities / Counting

Dec	Hex	Oct	Bin	Dec	Hex	Oct	Bin	Dec	Hex	Oct	Bin	Dec	Hex	Oct	Bin
0	0	000	00000000	16	10	020	00010000	32	20	040	00100000	48	30	060	00110000
1	1	001	00000001	17	11	021	00010001	33	21	041	00100001	49	31	061	00110001
2	2	002	00000010	18	12	022	00010010	34	22	042	00100010	50	32	062	00110010
3	3	003	00000011	19	13	023	00010011	35	23	043	00100011	51	33	063	00110011
4	4	004	00000100	20	14	024	00010100	36	24	044	00100100	52	34	064	00110100
5	5	005	00000101	21	15	025	00010101	37	25	045	00100101	53	35	065	00110101
6	6	006	00000110	22	16	026	00010110	38	26	046	00100110	54	36	066	00110110
7	7	007	00000111	23	17	027	00010111	39	27	047	00100111	55	37	067	00110111
8	8	010	00001000	24	18	030	00011000	40	28	050	00101000	56	38	070	00111000
9	9	011	00001001	25	19	031	00011001	41	29	051	00101001	57	39	071	00111001
10	A	012	00001010	26	1A	032	00011010	42	2A	052	00101010	58	3A	072	00111010
11	B	013	00001011	27	1B	033	00011011	43	2B	053	00101011	59	3B	073	00111011
12	C	014	00001100	28	1C	034	00011100	44	2C	054	00101100	60	3C	074	00111100
13	D	015	00001101	29	1D	035	00011101	45	2D	055	00101101	61	3D	075	00111101
14	E	016	00001110	30	1E	036	00011110	46	2E	056	00101110	62	3E	076	00111110
15	F	017	00001111	31	1F	037	00011111	47	2F	057	00101111	63	3F	077	00111111
64	40	100	01000000	80	50	120	01010000	96	60	140	01100000	112	70	160	01110000
65	41	101	01000001	81	51	121	01010001	97	61	141	01100001	113	71	161	01110001
66	42	102	01000010	82	52	122	01010010	98	62	142	01100010	114	72	162	01110010
67	43	103	01000011	83	53	123	01010011	99	63	143	01100011	115	73	163	01110011
68	44	104	01000100	84	54	124	01010100	100	64	144	01100100	116	74	164	01110100
69	45	105	01000101	85	55	125	01010101	101	65	145	01100101	117	75	165	01110101
70	46	106	01000110	86	56	126	01010110	102	66	146	01100110	118	76	166	01110110
71	47	107	01000111	87	57	127	01010111	103	67	147	01100111	119	77	167	01110111
72	48	110	01001000	88	58	130	01011000	104	68	150	01101000	120	78	170	01111000
73	49	111	01001001	89	59	131	01011001	105	69	151	01101001	121	79	171	01111001
74	4A	112	01001010	90	5A	132	01011010	106	6A	152	01101010	122	7A	172	01111010
75	4B	113	01001011	91	5B	133	01011011	107	6B	153	01101011	123	7B	173	01111011
76	4C	114	01001100	92	5C	134	01011100	108	6C	154	01101100	124	7C	174	01111100
77	4D	115	01001101	93	5D	135	01011101	109	6D	155	01101101	125	7D	175	01111101
78	4E	116	01001110	94	5E	136	01011110	110	6E	156	01101110	126	7E	176	01111110
79	4F	117	01001111	95	5F	137	01011111	111	6F	157	01101111	127	7F	177	01111111

1.3 BINARY SYSTEM

A binary system is made up Binary Digits. A Binary Digit can only be 0 and 1, arranged in a series of columns to represent all numerical quantities.

Binary numbers have many uses in mathematics and beyond. In the computer world "**binary digit**" is abbreviated to the word "**bit**".

Each bit in the binary system has a **place value** and a **weighted value** of 1, 2, 4, 8, 16, and so on assigned to it, ranging from right to left.

Binary System Application

Binary Systems are very useful in computer technology and computer programming languages that help in digital encoding. The Binary System can also be used in Boolean algebra.

Advantages and disadvantages

- The main advantage of using binary is that it is a base which is easily represented by electronic devices. The Binary System also simplifies use in coding, fewer computations and less computational errors.
- The main disadvantage of using binary is difficult to read and write for humans because of large number of binary with an equivalent decimal numbers.

1.4 ADD AND SUBTRACT IN OCTAL AND HEXADECIMAL

OCTAL ADDITION

Use the octal addition table to help you handle octal addition. To use this table, simply follow the directions used in this example:

Add 6_8 and 5_8

Locate **6** in column A then locate **5** in column B. The point where these two (2) columns intersect is the 'sum' of two (2) numbers.

+	0	1	2	3	4	5	6	7
0	0	1	2	3	4	5	6	7
1	1	2	3	4	5	6	7	10
2	2	3	4	5	6	7	10	11
3	3	4	5	6	7	10	11	12
4	4	5	6	7	10	11	12	13
5	5	6	7	10	11	12	13	14
6	6	7	10	11	12	13	14	15
7	7	10	11	12	13	14	15	16

A

Sum

B

Octal Addition Table

$$6_8 + 5_8 = 13_8$$

If SUM ≥ 8, the rule is:

SUM – 8 and carry 1 to the next significant bit

The sum of 6 and 5 is 11 which is more than 8. So, 11 – 8 = 3. Carry 1 to the next significant bit.

For Example!

Octal Addition

Example 1

Calculate $162_8 + 537_8 = ?$

Solution:

```
      1   1    <---- carry
      1   6   2
  +   5   3   7
  -------------
      7   2   1
  -------------
```

$\therefore 162_8 + 537_8 = 721_8$

Example 2

Calculate $136_8 + 636_8 = ?$

Solution:

```
          1    <---- carry
      1   3   6
  +   6   3   6
  -------------
      7   7   4
  -------------
```

$\therefore 136_8 + 636_8 = 774_8$

MATH DRILLS!

Calculate the followings without using calculator.

a. $456_8 + 123_8$ Answer: 601_8	b. $423_8 + 326_8$ Answer: 751_8	c. $354_8 + 506_8$ Answer: 1062_8
d. $134_8 + 427_8$ Answer: 563_8	e. $326_8 + 623_8$ Answer: 1151_8	f. $656_8 + 177_8$ Answer: 1055_8
g. $6712_8 + 15_8$ Answer: 6727_8	h. $1023_8 + 424_8$ Answer: 1447_8	i. $1456_8 + 5112_8$ Answer: 5112_8
j. $56712_8 + 215_8$ Answer: 57127_8	k. $11111_8 + 65302_8$ Answer: 76413_8	l. $26662_8 + 75442_8$ Answer: 124324_8

OCTAL SUBTRACTION

The subtraction of octal numbers follows the same rules as the subtraction of numbers in any other number system. The only variation is in borrowed numbers. Borrow is equal to the base of number system.

If you are working with octal system (base 8), you will borrow 8.

Octal Subtraction

Example 1

Calculate $44_8 - 6_8$ =?

Solution:

$$\begin{array}{rr} & {\scriptstyle 3}\ {\scriptstyle 8} \\ & \cancel{4}\ 4 \\ - & \quad 6 \\ \hline & 3\ 6 \end{array}$$

<---- borrow

$\therefore 44_8 - 6_8 = 36_8$

Example 2

Calculate $456_8 - 173_8$ =?

Solution:

$$\begin{array}{rr} & {\scriptstyle 3}\ {\scriptstyle 8} \\ & \cancel{4}\ 5\ 6 \\ - & 1\ 7\ 3 \\ \hline & 2\ 6\ 3 \end{array}$$

<---- borrow

$\therefore 456_8 - 173_8 = 263_8$

MATH DRILLS!

Calculate the followings without using calculator.

a. $532_8 - 174_8$ Answer: 336_8	b. $423_8 - 326_8$ Answer: 75_8	c. $712_8 - 15_8$ Answer: 675_8
d. $1023_8 - 424_8$ Answer: 377_8	e. $100_8 - 24_8$ Answer: 54_8	f. $273_8 - 127_8$ Answer: 144_8
g. $7243_8 - 4124_8$ Answer: 3117_8	h. $335_8 - 224_8$ Answer: 111_8	i. $6453_8 - 721_8$ Answer: 5532_8
j. $4343_8 - 526_8$ Answer: 3615_8	k. $250_8 - 40_8$ Answer: 210_8	l. $2303_8 - 116_8$ Answer: 2165_8

HEXADECIMAL ADDITION

Uses 10 digits and 6 letters, **0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F**. Letters represents numbers starting from 10.

A = 10, B = 11, C = 12, D = 13,
E = 14, F = 15

+	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
1	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	10
2	2	3	4	5	6	7	8	9	A	B	C	D	E	F	10	11
3	3	4	5	6	7	8	9	A	B	C	D	E	F	10	11	12
4	4	5	6	7	8	9	A	B	C	D	E	F	10	11	12	13
5	5	6	7	8	9	A	B	C	D	E	F	10	11	12	13	14
6	6	7	8	9	A	B	C	D	E	F	10	11	12	13	14	15
7	7	8	9	A	B	C	D	E	F	10	11	12	13	14	15	16
8	8	9	A	B	C	D	E	F	10	11	12	13	14	15	16	17
9	9	A	B	C	D	E	F	10	11	12	13	14	15	16	17	18
A	A	B	C	D	E	F	10	11	12	13	14	15	16	17	18	19
B	B	C	D	E	F	10	11	12	13	14	15	16	17	18	19	1A
C	C	D	E	F	10	11	12	13	14	15	16	17	18	19	1A	1B
D	D	E	F	10	11	12	13	14	15	16	17	18	19	1A	1B	1C
E	E	F	10	11	12	13	14	15	16	17	18	19	1A	1B	1C	1D
F	F	10	11	12	13	14	15	16	17	18	19	1A	1B	1C	1D	1E

X (columns) · Y (rows) · Sum

Hexadecimal Addition Table

To use this table, simply follow the directions used in this example:

Add A_{16} and B_{16}

Locate **A** in column X then locate **B** in column Y. The point where these two (2) columns intersect is the 'sum' of two (2) numbers.

$$A_{16} + B_{16} = 15_{16}$$

If SUM ≥ 16, the rule is:

SUM – 16 and carry 1 to the next significant bit

The sum of A and B is 21 which is more than 16.
So, 21 – 16 = 5. Carry 1 to the next significant bit.

For Example!

Hexadecimal Addition

Example 1

Calculate $55_{16} + 95_{16} = ?$

Solution:

$$\begin{array}{rr} & 5\ \ 5 \\ + & 9\ \ 5 \\ \hline & E\ \ A \end{array}$$

10 = A

$\therefore 55_{16} + 95_{16} = EA_{16}$

Example 2

Calculate $4A6_{16} + 1B3_{16} = ?$

Solution:

$$\begin{array}{rr} & \color{red}{1}\ \ \ \ \color{red}{\text{<---- carry}} \\ & 4\ \ A\ \ 6 \\ + & 1\ \ B\ \ 3 \\ \hline & 6\ \ 5\ \ 9 \end{array}$$

$\therefore 4A6_{16} + 1B3_{16} = 659_{16}$

MATH DRILLS!

Calculate the followings without using calculator.

a. $4A_{16} + 1F_{16}$ Answer: 69_{16}	b. $B23_{16} + 326_{16}$ Answer: $E49_{16}$	c. $354_{16} + 5E6_{16}$ Answer: $93A_{16}$
d. $134_{16} + 427_{16}$ Answer: $55B_{16}$	e. $326_{16} + 623_{16}$ Answer: 949_{16}	f. $656_{16} + 177_{16}$ Answer: $7CD_{16}$
g. $6712_{16} + 15_{16}$ Answer: 6727_{16}	h. $1023_{16} + 424_{16}$ Answer: 1447_{16}	i. $1456_{16} + 5112_{16}$ Answer: 6568_{16}
j. $ABC_{16} + DEF_{16}$ Answer: $18AB_{16}$	k. $FEB_{16} + 123_{16}$ Answer: $110E_{16}$	l. $9A_{16} + 9E_{16}$ Answer: 138_{16}

HEXADECIMAL SUBTRACTION

The subtraction of hexadecimal numbers follows the same rules as the subtraction of numbers in any other number system. The only variation is in borrowed numbers. Borrow is equal to the base of number system.

If you are working with hexadecimal system (base 16), you will borrow 16.

Hexadecimal Subtraction

Example 1

Calculate $5CD2_{16} - 2A0_{16}$ =?

Solution:

$$\begin{array}{rcccc} & 5 & C & D & 2 \\ - & & 2 & A & 0 \\ \hline & 5 & A & 3 & 2 \end{array}$$

$\therefore 5CD2_{16} - 2A0_{16} = 5A32_{16}$

Example 2

Calculate $4A6_{16} - 1B3_{16}$ =?

Solution:

$$\begin{array}{rcccc} & \not{4}^{3} & A^{16} & 6 & \leftarrow \text{borrow} \\ - & 1 & B & 3 & \\ \hline & 2 & F & 3 & \end{array}$$

$\therefore 4A6_{16} - 1B3_{16} = 2F3_{16}$

MATH DRILLS!

Calculate the followings without using calculator.

a. $5F2_{16} - 174_{16}$ Answer: $47E_{16}$	b. $A23_{16} - 26_{16}$ Answer: $9FD_{16}$	c. $56B_{16} - 24_{16}$ Answer: 547_{16}
d. $1023_{16} - 424_{16}$ Answer: BFF_{16}	e. $100_{16} - 24_{16}$ Answer: DC_{16}	f. $273_{16} - 127_{16}$ Answer: $14C_{16}$
g. $7E43_{16} - 124_{16}$ Answer: $7D1F_{16}$	h. $3BC_{16} - 224_{16}$ Answer: 198_{16}	i. $ABCD_{16} - EF_{16}$ Answer: $AADE_{16}$
j. $4343_{16} - 5B6_{16}$ Answer: $3D8D_{16}$	k. $F50_{16} - 40_{16}$ Answer: $F10_{16}$	l. $2303_{16} - 116_{16}$ Answer: $21ED_{16}$

1.5 BINARY TO DECIMAL AND DECIMAL TO BINARY

BINARY TO DECIMAL

To convert binary to decimal, basic knowledge of how to read binary numbers may help. In the positional system of binary, each bit (binary digit) is a power of 2. This means that each binary number can be represented as powers of 2, with the rightmost being in position 2^0.

For Example!

Convert 11010_2 to decimal number

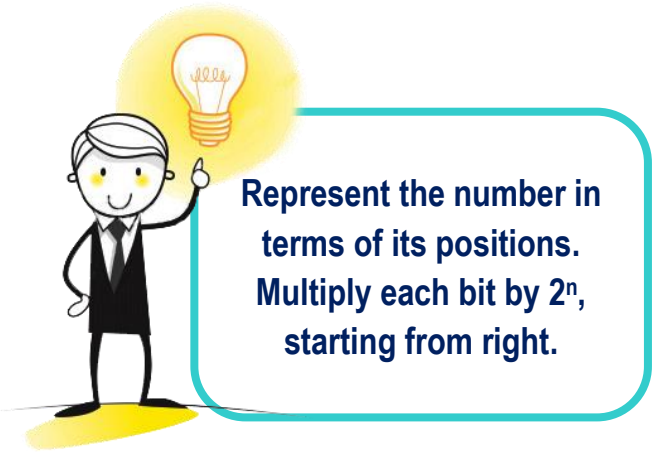
Method 1:

$(1 \times 2^4) + (1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (0 \times 2^0)$
$= 16 + 8 + 0 + 2 + 0$
$= 26_{10}$

Method 2:

$0 \times 2^0 = 0$
$1 \times 2^1 = 2$
$0 \times 2^2 = 0$
$1 \times 2^3 = 8$
$1 \times 2^4 = 16$
26_{10}

add



$\therefore 11010_2 = 26_{10}$

MATH DRILLS!

Convert the followings binary numbers into decimal.

a. 11001_2 Answer: 25	**b.** 10010_2 Answer: 18	**c.** 11111_2 Answer: 31
d. 110001_2 Answer: 49	**e.** 110111_2 Answer: 55	**f.** 101110_2 Answer: 46

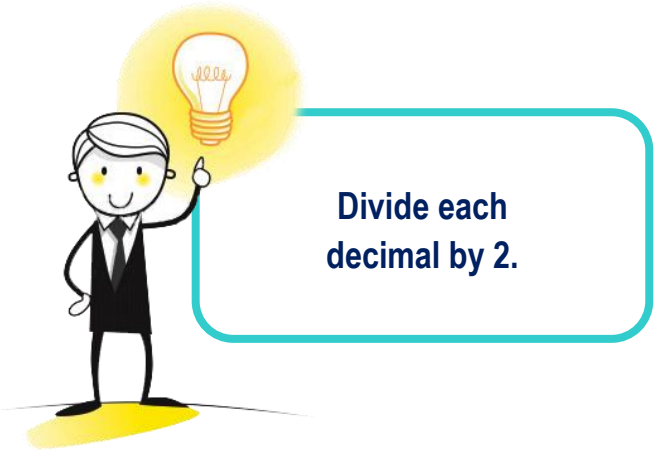
DECIMAL TO BINARY

One of the methods to convert decimal to binary is **by dividing the given decimal number recursively by 2**. Then, the remainders are noted down till we get 0 as the final quotient. After this step, these remainders are written in reverse order to get the binary value of the given decimal number.

For Example!

Convert 66_{10} to binary number

2	66	
2	33	0
2	16	1
2	8	0
2	4	0
2	2	0
2	1	0
	0	1



$\therefore \quad 66_{10} = 1000010_2$

MATH DRILLS!

Convert the followings decimal numbers into binary.

a. 23_{10} Answer: 10111_2	**b.** 37_{10} Answer: 100101_2	**c.** 40_{10} Answer: 101000_2
d. 51_{10} Answer: 110011_2	**e.** 64_{10} Answer: 1000000_2	**f.** 76_{10} Answer: 1001100_2

1.6 DATA ORGANIZATION

In pure mathematics a value may take an arbitrary number of bits. Computers, on the other hand, generally work with some specific number of bits.

Common collections are:

1. **Bits**
   A single numerical unit in the binary number system. Bit is short for **BI**nary digi**T**. It is the smallest unit of digital data.

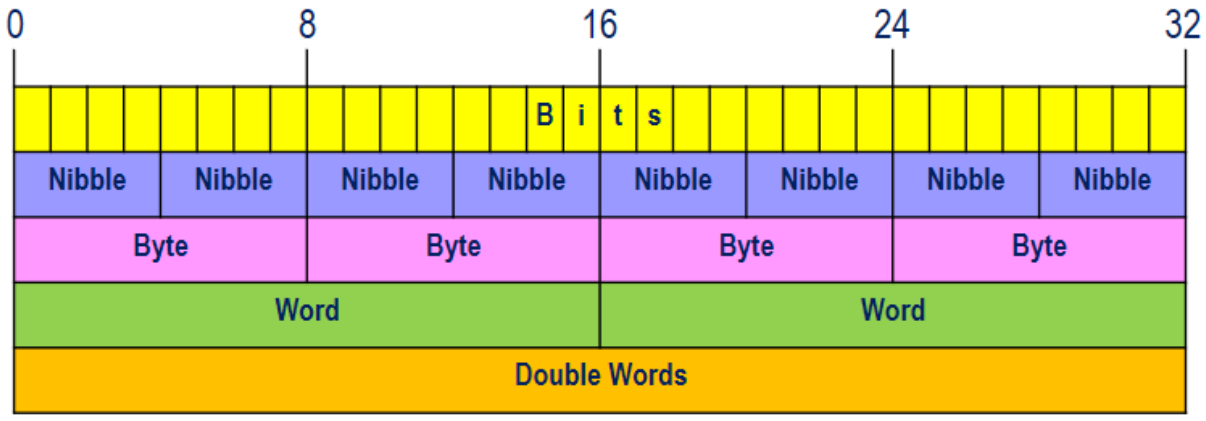
2. **Nibbles**
   Four (4) bits in series, or half an 8-bit byte. A nibble is used to represent decimal numbers in BCD (binary coded decimal) or hexadecimal in binary.

3. **Bytes**
   A series of eight (8) bits.

4. **Words**
   A group of sixteen (16) bits.

5. **Double Words**
   A pair of words which have thirty-two (32) bits.

The following diagram shows the relative sizes of the most commonly-sized “collections” of binary information:



EXAMPLES >> HOW TO CONVERT	
Word to Nibble	**Nibble to Word**
MULTIPLY the digital storage value by 4 **(1 word = 4 nibbles)** **Example**: Convert 11 words to nibble. **Solution**: 11 word = 11 × 4 nibble = 44 nibble	**DIVIDE** the digital storage value by 4 **Example**: Convert 36 nibbles to word. **Solution**: 36 nibble = 36 / 4 word = 9 word
Word to Bit	**Bit to Word**
MULTIPLY the digital storage value by 16 **(1 word = 16 bits)** **Example**: Convert 7 words to bit. **Solution**: 7 word = 7 × 16 bit = 112 bit	**DIVIDE** the digital storage value by 16 **Example**: Convert 28 bits to word. **Solution**: 28 nibble = 24 / 16 word = 1.5 word

MATH DRILLS!

Write the followings in terms of data organization stated in bracket.

a. 16 bits [nibbles] Answer: 4 nibbles	**b. 4 words [nibbles]** Answer: 16 nibbles	**c. 5 bytes [nibbles]** Answer: 10 nibbles
d. 10 bytes [bits] Answer: 80 bits	**e. 2 words [bits]** Answer: 32 bits	**f. 23 nibbles [bits]** Answer: 92 bits
g. 48 bits [word] Answer: 3 words	**h. 100 nibbles [word]** Answer: 25 words	**i. 2016 bits [bytes]** Answer: 252 bytes

1.7 UNIT, NUMBER, BASE/RADIX, POSITIONAL NOTATION, MOST AND LEAST SIGNIFICANT DIGITS

Unit and Number

- Simplest terms, the basis upon which all other numbers are defined.
- Unit is a single object. A number is a symbol representing a unit or a quantity.

Base / Radix

- The base of a system, more properly called the RADIX (r), is the number of different values that can be expressed using a single digit including zero (0) in the number system.
- A number of system radix (r), typically has a set of r allowed digits belongs to {0, 1, …, r – 1}. Therefore, the decimal system has a radix of 10, the octal system has a radix of 8, hexadecimal is radix 16, and binary is radix 2.

Decimal	***Octal***	***Hexadecimal***	***Binary***
Base = 10 → r	*Base = 8 → r*	*Base = 16 → r*	*Base = 2 → r*
0 to r – 1	*0 to r – 1*	*0 to r – 1*	*0 to r – 1*
0 to 10 – 1	*0 to 8 – 1*	*0 to 16 – 1*	*0 to 2 – 1*
=> 0 to 9	*=> 0 to 7*	*=> 0 to F*	*=> 0 to 1*

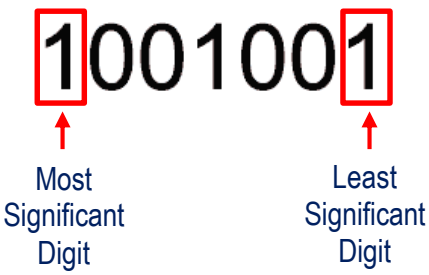
Positional Notation

- A system of expressing number in which the digits are arranged in succession, the position of each digit has a place value, and the number is equal to the sum of the products of each digit by its place value.
- Example:

$$
\begin{aligned}
953 &= (9 \times 10^2) + (5 \times 10^1) + (3 \times 10^0) \\
&= 900 + 50 + 3 \\
&= 953
\end{aligned}
$$

Most and Least Significant Digits

- The leftmost nonzero digit is the most significant. The rightmost digit is the least significant.
- Examples: 1001001



02

OCTAL NUMBERING SYSTEM

2.1

- Octal to Decimal
- Decimal to Octal

2.2

- Octal to Binary
- Binary to Octal

2.1 OCTAL TO DECIMAL & DECIMAL TO OCTAL

OCTAL TO DECIMAL

To convert octal to decimal, we need to **multiply the octal digits with the power of 8** starting from the rightmost being in position 8^0.

For Example!

Convert 761_8 to decimal number

Method 1:

Represent the number in terms of its positions.

$(7 \times 8^2) + (6 \times 8^1) + (1 \times 8^0)$
$= 448 + 48 + 1$
$= 497_{10}$

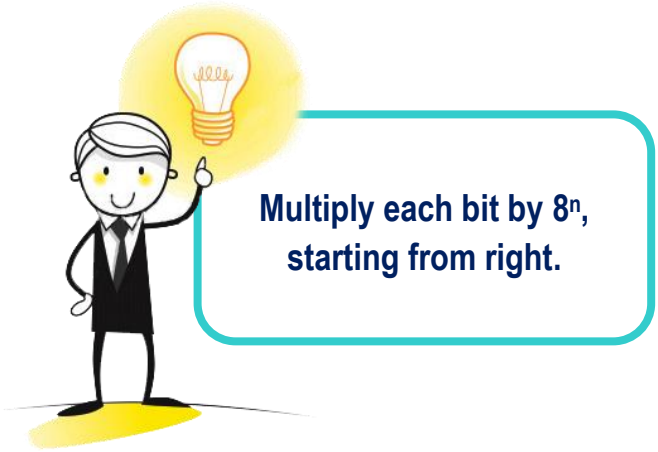
Method 2:

Represent the number in terms of its positions.

$1 \times 8^0 = 1$
$6 \times 8^1 = 48$
$7 \times 8^2 = 448$
497_{10}

add

$\therefore 761_8 = 497_{10}$



MATH DRILLS!

Convert the followings octal numbers into decimal.

a. 16_8 Answer: 14	b. 100_8 Answer: 64	c. 222_8 Answer: 146
d. 457_8 Answer: 303	e. 6123_8 Answer: 3155	f. 1155_8 Answer: 621

DECIMAL TO OCTAL

One of the methods to convert decimal to octal is **by dividing the given decimal number recursively by 8**. Then, the remainders are noted down till we get 0 as the final quotient. After this step, these remainders are written in reverse order to get the octal value of the given decimal number.

For Example!

Convert decimal to octal number

Example 1: Convert 66_{10} to an octal number

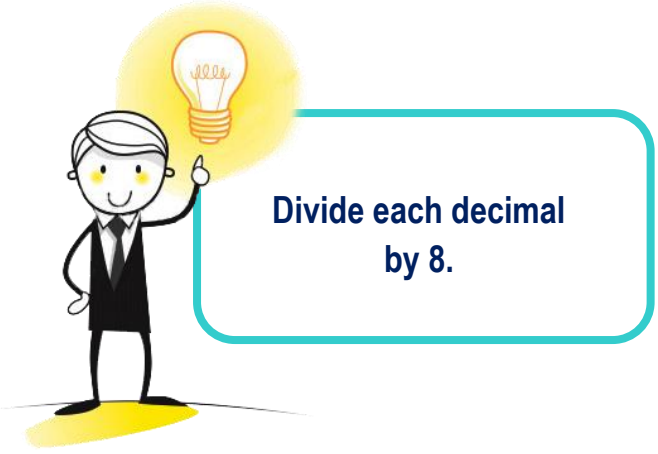
8	66	
8	8	2
8	1	0
	0	1

$\therefore \quad 66_{10} = 102_8$

Example 2: Convert 103_{10} to an octal number

8	103	
8	12	7
8	1	4
	0	1

$\therefore \quad 103_{10} = 147_8$



MATH DRILLS!

Convert the followings decimal numbers into octal.

a. 18_{10} Answer: 22_8	**b.** 29_{10} Answer: 35_8	**c.** 46_{10} Answer: 56_8
d. 73_{10} Answer: 111_8	**e.** 105_{10} Answer: 151_8	**f.** 243_{10} Answer: 363_8

2.2 OCTAL TO BINARY & BINARY TO OCTAL

OCTAL TO BINARY

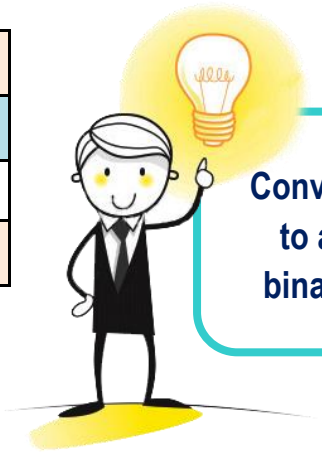
Each octal digit represents three (3) binary digits. Therefore, one (1) octal digit should give three (3) binary digits (bits).

Convert octal to binary number

Example 1: Convert 761_8 to a binary number.

7			6			1		
2^2	2^1	2^0	2^2	2^1	2^0	2^2	2^1	2^0
4 + 2 + 1			4 + 2 + 1			4 + 2 + 1		
1	1	1	1	1	0	0	0	1

$\therefore \quad 761_8 = 111110001_2$



Convert each octal digit to a 3-bit equivalent binary representation.

Example 2: Convert 2475_8 to a binary number.

2			4			7			5		
2^2	2^1	2^0	2^2	2^1	2^0	2^2	2^1	2^0	2^2	2^1	2^0
4 + 2 + 1			4 + 2 + 1			4 + 2 + 1			4 + 2 + 1		
0	1	0	1	0	0	1	1	1	1	0	1

$\therefore \quad 2475_8 = 1\ 0\ 1\ 0\ 0\ 1\ 1\ 1\ 1\ 0\ 1_2$

MATH DRILLS!

Convert the followings octal numbers into binary.

a. 46_8 Answer: 100110_2	**b.** 70_8 Answer: 111000_2
c. 672_8 Answer: 110111010_2	**d.** 155_8 Answer: 1101101_2
e. 1073_8 Answer: 1000111011_2	**f.** 1550_8 Answer: 1101101000_2

BINARY TO OCTAL

The binary number is grouped into a series of threes (3's) starting from the rightmost side. Then we must convert those groups into octal digit.

For Example!

Convert binary to octal number

Example 1: Convert 11 010_2 to an octal number.

	1	1	0	1	0
2^2	2^1	2^0	2^2	2^1	2^0
4 + 2 + 1			4 + 2 + 1		
3			2		

∴ **$11\ 010_2 = 32_8$**

Example 2: Convert 10 101 111_2 to an octal number.

	1	0	1	0	1	1	1	1
2^2	2^1	2^0	2^2	2^1	2^0	2^2	2^1	2^0
4 + 2 + 1			4 + 2 + 1			4 + 2 + 1		
2			5			7		

∴ **$10\ 101\ 111_2 = 257_8$**

MATH DRILLS!

Convert the followings binary numbers into octal.

a. 10110_2 Answer: 26_8	**b.** 11111_2 Answer: 37_8
c. 110011_2 Answer: 63_8	**d.** 101010_2 Answer: 52_8
e. 1000001_2 Answer: 101_8	**f.** 1111000_2 Answer: 170_8
g. 10110000 Answer: 260_8	**h.** 10100011 Answer: 243_8

03

HEXADECIMAL NUMBERING SYSTEM

3.1

- Hexadecimal to Decimal
- Decimal to Hexadecimal

3.2

- Hexadecimal to Binary
- Binary to Hexadecimal

3.3

- Hexadecimal to Octal
- Octal to Hexadecimal

3.1 HEXADECIMAL TO DECIMAL & DECIMAL TO HEXADECIMAL

HEXADECIMAL TO DECIMAL

To convert hexadecimal to decimal, we need to **multiply the hexadecimal digits with the power of 16** starting from the rightmost being in position 16^0.

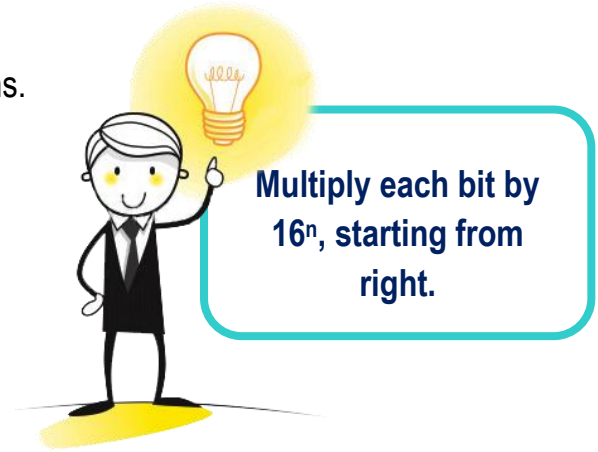
For Example!

Convert ACE_{16} to decimal number

Method 1:

Represent the number in terms of its positions.

$$(A \times 16^2) + (C \times 16^1) + (E \times 16^0)$$
$$= (10 \times 256) + (12 \times 16) + (14 \times 1)$$
$$= 2560 + 192 + 14$$
$$= 2766_{10}$$



Method 2:

Represent the number in terms of its positions.

$E \times 16^0$	=	14×1	= 14
$C \times 16^1$	=	12×16	= 192
$A \times 16^2$	=	10×256	= 2560
			2766_{10}

add

$\therefore ACE_{16} = 2766_{10}$

MATH DRILLS!

Convert the followings Base 16 numbers to Base 10.

a. $18A_{16}$ Answer: 394	b. $2B9_{16}$ Answer: 649	c. $C46_{16}$ Answer: 3142
d. $73D1_{16}$ Answer: 29649	e. $E105_{16}$ Answer: 57605	f. $24FA3_{16}$ Answer: 151459
g. ABC_{16} Answer: 2748	h. $A4_{16}$ Answer: 164	i. $1BED_{16}$ Answer: 7149

DECIMAL TO HEXADECIMAL

One of the methods to convert decimal to hexadecimal is **by dividing the given decimal number recursively by 16**. Then, the remainders are noted down till we get 0 as the final quotient. After this step, these remainders are written in reverse order to get the hexadecimal value of the given decimal number.

For Example!

Convert decimal to hexadecimal number

Example 1: Convert 465_{10} to hexadecimal number.

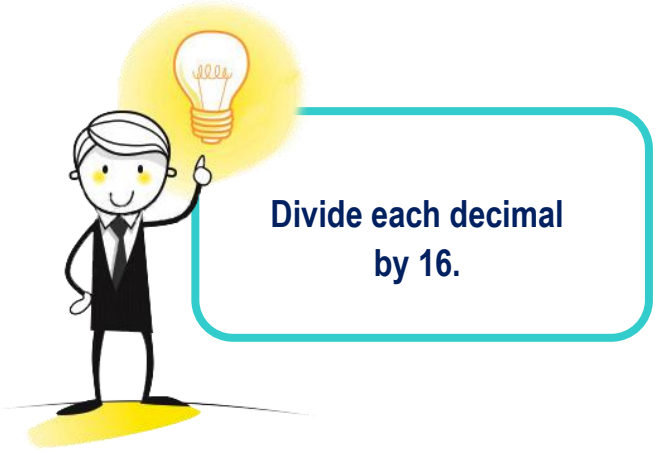
16	465	
16	29	1
16	1	13 = D
	0	1

$\therefore \quad 465_{10} = 1D1_{16}$

Example 2: Convert 3005_{10} to hexadecimal number.

16	3005	
16	187	13 = D
16	11	11 = B
	0	11 = B

$\therefore \quad 3005_{10} = BBD_{16}$



MATH DRILLS!

Convert the followings Base 10 numbers to Base 16.

a. 48_{10} Answer: 30_{16}	**b.** 89_{10} Answer: 59_{16}	**c.** 141_{10} Answer: $8D_{16}$
d. 333_{10} Answer: $14D_{16}$	**e.** 502_{10} Answer: $1F6_{16}$	**f.** 746_{10} Answer: $2EA_{16}$
g. 2022_{10} Answer: $7E6_{16}$	**h.** 1979_{10} Answer: $7BB_{16}$	**i.** 43_{10} Answer: $2B_{16}$

3.2 HEXADECIMAL TO BINARY & BINARY TO HEXADECIMAL

HEXADECIMAL TO BINARY

Each hexadecimal digit represents four (4) binary digits. Therefore, one (1) hexadecimal digit should give four (4) binary digits (bits).

Convert hexadecimal to binary number

Example 1: Convert ACE_{16} to a binary number.

A = 10				C = 12				E = 14			
2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0
8 + 4 + 2 + 1				8 + 4 + 2 + 1				8 + 4 + 2 + 1			
1	0	1	0	1	1	0	0	1	1	1	0

$\therefore$ $ACE_{16} = 1010\ 1100\ 1110_2$

Convert each hexadecimal digit to a 4-bit equivalent binary representation.

Example 2: Convert $2B3D_{16}$ to a binary number.

3				B = 11				3				D = 13			
2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0
8 + 4 + 2 + 1				8 + 4 + 2 + 1				8 + 4 + 2 + 1				8 + 4 + 2 + 1			
0	0	1	0	1	0	1	1	0	0	1	1	1	1	0	1

$\therefore$ $2B3D_{16} = 10\ 1011\ 0011\ 1101_2$

MATH DRILLS!

Convert the followings Base 16 numbers to Base 2.

a. 46_{16} Answer: $100\ 0110_2$	**b.** $70D_{16}$ Answer: $111\ 0000\ 1101_2$
c. $6A2_{16}$ Answer: $110\ 1010\ 0010_2$	**d.** $1EB_{16}$ Answer: $1\ 1110\ 1011_2$
e. $10A_{16}$ Answer: $1\ 0000\ 1010_2$	**f.** $1500CC_{16}$ Answer: $1\ 0101\ 0000\ 0000\ 1100_2$

BINARY TO HEXADECIMAL

The binary number is grouped into a series of fours (4's) starting from the rightmost side. Then we must convert those groups into hexadecimal digit.

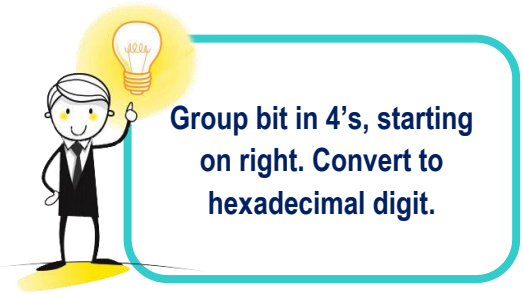
For Example!

Convert binary to hexadecimal number

Example 1: Convert 11 1011 1011_2 to hexadecimal number.

		1	1	1	0	1	1	1	0	1	1
2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0
8 + 4 + 2 + 1				8 + 4 + 2 + 1				8 + 4 + 2 + 1			
3				11				11			
3				B				B			

∴ $11\ 1011\ 1011_2 = 3BB_{16}$



Example 2: Convert 1111 0010 1100 0111_2 to hexadecimal number.

1	1	1	1	0	0	1	0	1	1	0	0	0	1	1	1
2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0
8 + 4 + 2 + 1				8 + 4 + 2 + 1				8 + 4 + 2 + 1				8 + 4 + 2 + 1			
3				2				12				7			
F				2				C				7			

∴ $1111\ 0010\ 1100\ 0111_2 = F2C7_{16}$

MATH DRILLS!

Convert the followings Base 2 numbers to Base 16.

a. $1\ 0110\ 1101_2$ Answer: $16D_{16}$	**b.** $1111\ 1001_2$ Answer: $F9_{16}$
c. $11\ 0011\ 0010_2$ Answer: 332_{16}	**d.** $1\ 0101\ 0111_2$ Answer: 157_{16}
e. $100\ 0001\ 0010_2$ Answer: 412_{16}	**f.** $111\ 1000\ 0111_2$ Answer: 787_{16}
g. $10\ 1100\ 0011\ 0101_2$ Answer: $2C35_{16}$	**h.** $1\ 0100\ 0110\ 1010_2$ Answer: $146A_{16}$

3.3 HEXADECIMAL TO OCTAL & OCTAL TO HEXADECIMAL

HEXADECIMAL TO OCTAL

Use binary as an intermediary

1. Convert each hexadecimal digit a 4-bit equivalent binary representation
2. Group bit in 3's, starting on right
3. Convert to octal digit

For Example!

Convert hexadecimal to octal number

Example 1: Convert $BA5_{16}$ to an octal number.

B = 11				A = 10				5			
8 + 4 + 2 + 1				8 + 4 + 2 + 1				8 + 4 + 2 + 1			
1	0	1	1	1	0	1	0	0	1	0	1
4 + 2 + 1			4 + 2 + 1			4 + 2 + 1			4 + 2 + 1		
5			6			4			5		

∴ $BA5_{16} = 5645_8$

Example 2: Convert $F4CE_{16}$ to an octal number.

First, change the number to binary system:

F = 15				4				C = 12				E = 14			
8 + 4 + 2 + 1				8 + 4 + 2 + 1				8 + 4 + 2 + 1				8 + 4 + 2 + 1			
1	1	1	1	0	1	0	0	1	1	0	0	1	1	1	0

Then, group the binary digit into 3 bits per group:

0	0	1	1	1	1	0	1	0	0	1	1	0	0	1	1	1	0
4 + 2 + 1			4 + 2 + 1			4 + 2 + 1			4 + 2 + 1			4 + 2 + 1			4 + 2 + 1		
1			7			2			3			1			6		

∴ **$F4CE_{16} = 172316_8$**

MATH DRILLS!

Convert the followings hexadecimal numbers into octal.

a. 25_{16} Answer: 45_8	b. $3D1_{16}$ Answer: 1721_8
c. $6A13_{16}$ Answer: 65023_8	d. $E48B_{16}$ Answer: 162213_8
e. $ADAB_{16}$ Answer: 126653_8	f. $FB20_{16}$ Answer: 175440_8

OCTAL TO HEXADECIMAL

Use binary as an intermediary

1. Convert each octal digit a 3-bit equivalent binary representation
2. Group bit in 4's, starting on right
3. Convert to hexadecimal digit

Convert an octal number to a hexadecimal number

Example 1: 107_8 → $\_\_\_\_{}_{16}$

1			0			7		
4 + 2 + 1			4 + 2 + 1			4 + 2 + 1		
0	0	1	0	0	0	1	1	1
	8 + 4 + 2 + 1					8 + 4 + 2 + 1		
	4					7		

∴ $107_8 = 47_{16}$

Example 2: 1076_8 → $\_\_\_\_{}_{16}$

1			0			7			6		
4 + 2 + 1			4 + 2 + 1			4 + 2 + 1			4 + 2 + 1		
0	0	1	0	0	0	1	1	1	1	1	0
8 + 4 + 2 + 1			8 + 4 + 2 + 1			8 + 4 + 2 + 1					
2			3			14 = E					

∴ $1076_8 = 23E_{16}$

MATH DRILLS!

Convert the followings octal numbers into hexadecimal.

a. 246_8 Answer: $A6_{16}$	**b.** 577_8 Answer: $17F_{16}$
c. 6720_8 Answer: $DD0_{16}$	**d.** 3153_8 Answer: $66B_{16}$
e. 1331_8 Answer: $2D9_{16}$	**f.** 1122_8 Answer: 252_{16}

TABLE: CONVERSION OF NUMBER SYSTEM

From / To	DECIMAL	BINARY	OCTAL	HEXADECIMAL
DECIMAL		Divide by 2	Divide by 8	Divide by 16
BINARY	Multiply each bit by 2^n		• Group bit in 3's, starting on right. • Convert to octal digit	• Group bit in 4's, starting on right. • Convert to hexa. digit
OCTAL	Multiply each bit by 8^n	Convert each octal digit to a 3-bit equivalent binary representation		Use binary as an intermediary
HEXADECIMAL	Multiply each bit by 16^n	Convert each hexa. digit to a 4-bit equivalent binary representation	Use binary as an intermediary	

04

BINARY ARITHMETIC

4.1

Binary Arithmetic Operations

Addition, Subtraction and Multiplication

4.1 BINARY ARITHMETIC OPERATIONS

BINARY ADDITION

Rules:

A	B	A + B
0	0	0
0	1	1
1	0	1
1	1	0 and carry 1 to the next more significant bit

Example 1:

	1				*1*	*carries*
	1	0	1	0	1	
+	1	1	0	0	1	
1	**0**	**1**	**1**	**1**	**0**	

Example 2:

			1	*1*		*carries*
	1	0	0	1	1	
+		1	0	1	1	
	1	**1**	**1**	**1**	**0**	

MATH DRILLS!

Calculate.

a. 1101 + 1000 Answer: 10101	**b. 1111 + 1010** Answer: 11001
c. 1100110 + 100 Answer: 1101010	**d. 1010101 + 11010** Answer: 1101111
e. 100110 + 100101 Answer: 1001011	**f. 1111111 + 100010** Answer: 10100001

BINARY SUBTRACTION

Rules:

A	B	A - B
0	0	0
0	1	1 and borrow 1 from the next more significant bit
1	0	1
1	1	0

Example 1:

```
      0  2          borrow
     1̸ 0 1 0 1
-      1 0 0 1
  -------------
     0 1 1 0 0
  -------------
```

Example 2:

```
        1
     0  2  2       borrow
    1̸ 0̸ 0 1 1
-       1 1 1 1
  -------------
     0 0 1 0 0
  -------------
```

If you are working with binary system (base 2), you will borrow 2.

MATH DRILLS!

Calculate.

a. 1101 – 1000 Answer: 101	**b. 1111 – 1010** Answer: 101
c. 1100110 – 100 Answer: 1100010	**d. 1010101 – 11010** Answer: 111011
e. 1110001 – 10111 Answer: 1011010	**f. 10000000 – 1000101** Answer: 111011

BINARY MULTIPLICATION

Rules:

A	B	A x B
0	0	0
0	1	0
1	0	0
1	1	1

Example 1:

				1	1	1	0	
×				1	0	1	1	
				1	1	1	0	
			1	1	1	0		
		0	0	0	0			
+	1	1	1	0				
1	**0**	**0**	**1**	**1**	**0**	**1**	**0**	

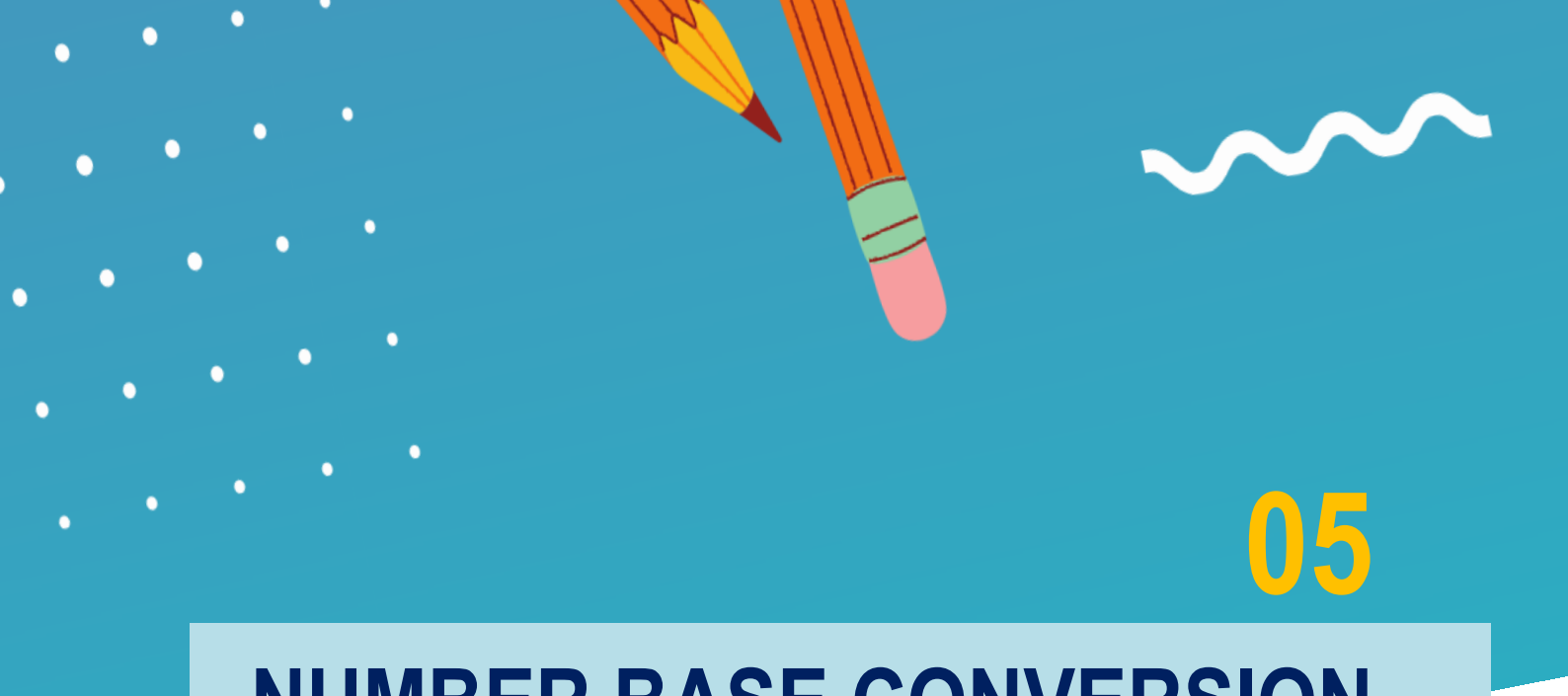
Example 2:

		1	1	1	
×		1	0	0	
1	**1**	**1**	**0**	**0**	

MATH DRILLS!

Calculate.

a. 1101 × 100 Answer:11 0100	**b. 1111 × 101** Answer:100 1011
c. 11001 × 1000 Answer:1100 1000	**d. 10101 × 1101** Answer:1 0001 0001
e. 11001 × 1110 Answer: 1 0101 1110	**f. 10000 × 1010** Answer: 1010 0000



05

NUMBER BASE CONVERSION USING SCIENTIFIC CALCULATOR

5.1

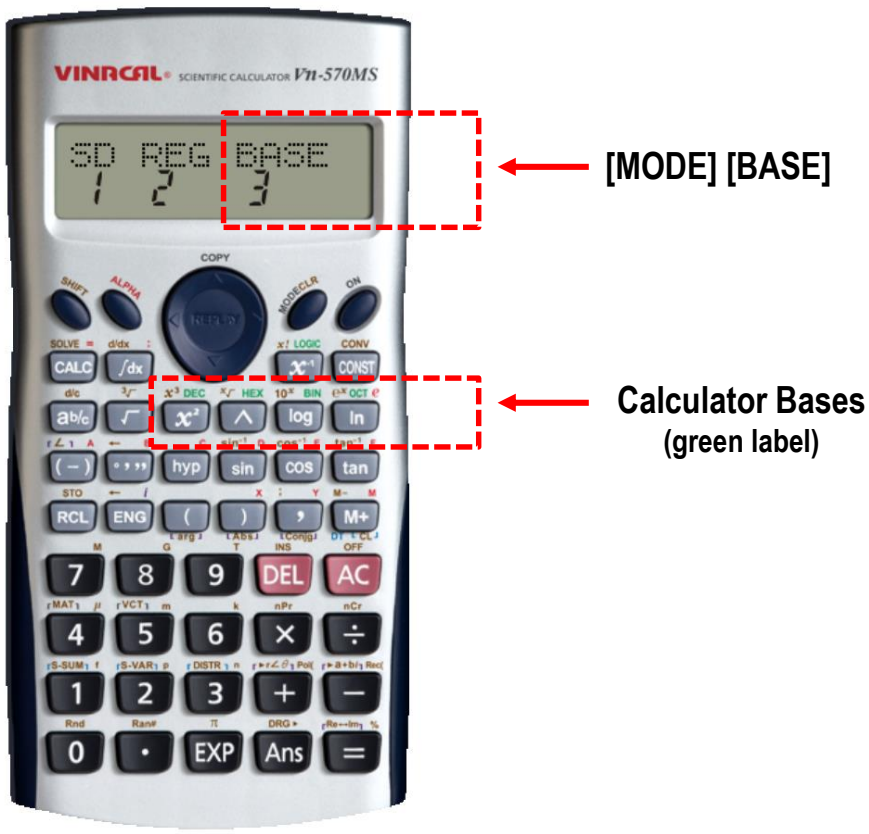
Convert One Base to Another

5.1 CONVERT ONE BASE TO ANOTHER

Before starting the calculation, you must first enter the correct mode related to the type of calculation you want to perform. The number base can be called from the calculator using the following mode operation **[MODE] [BASE]**. The calculator can be used to calculate the following bases: Decimal (Base 10), Binary (Base 2), Octal (Base 8) and Hexadecimal (Base 16).

Basically, calculator bases represented as **BIN**-Binary, **DEC**-Decimal, **OCT**-Octal and **HEX**-Hexadecimal. The green label is reserved for basic number calculations. This allows you to add / subtract / divide and multiply in different number bases.

The calculation mode can be returned to the initial default by pressing the **[MODE] [COMP]**.



Calculator

CONVERT BINARY TO DECIMAL

Example 1: Convert 10011_2 to decimal.

Procedure:

1. Press **[MODE] [BASE] [BIN] [1001] [=] [DEC]** (Result: 19).
2. Thus, the result is 19 in decimal.

CONVERT OCTAL TO DECIMAL

Example 2: Convert 2467_8 to decimal.

Procedure:

1. Press [**MODE] [BASE] [OCT] [2467] [=] [DEC]** (Result: 1335).
2. Thus, the result is 1335 in decimal.

CONVERT HEXADECIMAL TO DECIMAL

Example 3: Convert $F14E_{16}$ to decimal.

Procedure:

1. Press [**MODE] [BASE] [HEX] [F14E] [=] [DEC]** (Result: 61774).
2. Thus, the result is 61774 in decimal.

CONVERT DECIMAL TO HEXADECIMAL

Example 4: Convert 47818_{10} to hexadecimal.

Procedure:

1. Press [**MODE] [BASE] [DEC] [47818] [=] [HEX]** (Result: BACA).
2. Thus, the result is BACA in hexadecimal.

CONVERT DECIMAL TO OCTAL

Example 5: Convert 47818_{10} to octal.

Procedure:

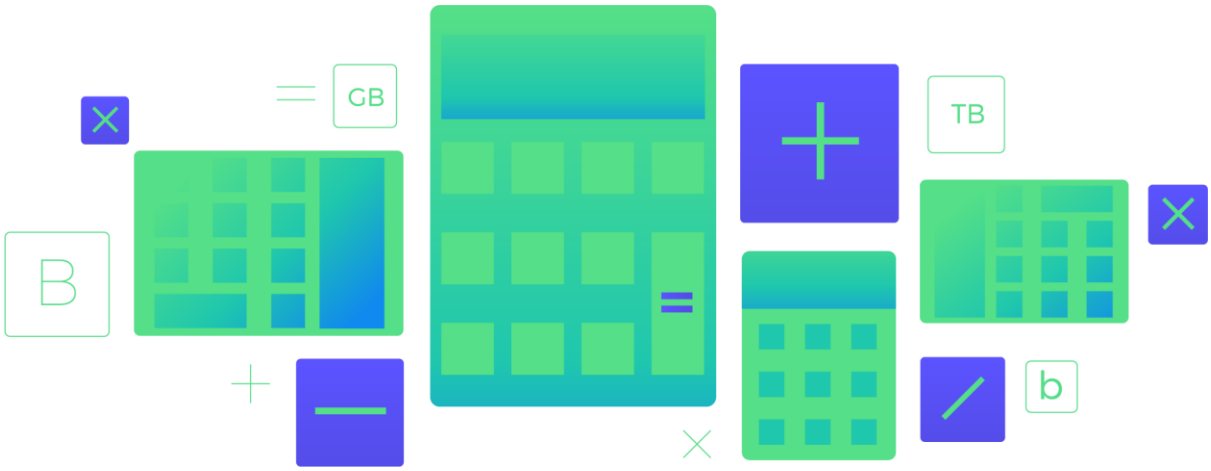
1. Press **[MODE] [BASE] [DEC] [47818] [=] [OCT]** (Result: 135312).
2. Thus, the result is 135312 in octal.

CONVERT DECIMAL TO BINARY

Example 6: Convert 468_{10} to binary.

Procedure:

1. Press **[MODE] [BASE] [DEC] [468] [=] [BIN]** (Result: 111010100).
2. Thus, the result is 111010100 in binary.



HOMEWORK

FINAL EXAMINATION QUESTION SAMPLE

HOMEWORK

1. Convert the binary numbers into decimal numbers:
   a) 11
   b) 101
   c) 1111
   d) 110111011
   e) 1111100011110011

2. Convert the decimal numbers into binary numbers:
   a) 7
   b) 13
   c) 128
   d) 1678
   e) 12359

3. Convert the following binary numbers to hexadecimal (base-16):
   a) 0111
   b) 1101
   c) 1011011
   d) 11101100
   e) 100101101
   f) 0101101011110000
   g) 0000000000000000001
   h) 11001010111001101011010011

4. Fill in the blanks:

Decimal	Binary	Octal	Hexadecimal
33			
	1110101		
		703	
			1AF

5. Convert the following hex numbers to binary:
   a) DEAD
   b) AF051257
   c) C9FF2A9
   d) 5E5E
   e) 123456789
   f) ABCDEF
   g) B0C
   h) 1010

6. Convert the following octal (base-8) numbers to decimal:
   a) 4
   b) 10
   c) 777
   d) 05726
   e) 183242

7. Convert the following decimal numbers to octal:
   a) 5
   b) 9
   c) 625
   d) 1,024
   e) 32,767

8. Add the following 4-bit binary numbers:
   a) $1011_2 + 1001_2$
   b) $1100_2 + 0110_2$
   c) $1010_2 + 0011_2$
   d) $1101_2 + 1011_2$
   e) $1001_2 + 0111_2$
   f) $1100_2 + 1001_2$

9. Add the following 8-bit binary numbers:
   a) $11001010_2 + 10011010_2$
   b) $10011100_2 + 01111001_2$
   c) $11001011_2 + 10000011_2$
   d) $11100001_2 + 10011101_2$
   e) $10000001_2 + 01100110_2$
   f) $10010011_2 + 10000111_2$

10. Calculate the binary numbers:

a) 11 – 10	b) 110 – 10	c) 1111 – 110	d) 100 – 10
e) 100 – 11	f) 1000 – 11	g) 1101 – 110	h) 11011 – 110
i) 1111 – 111	j) 110101 – 1010	k) 11011 – 111	l) 11110 – 111

11. Subtract the following 4-bit binary numbers:
   a) $1011_2 - 1001_2$
   b) $1100_2 - 0110_2$
   c) $1010_2 - 0011_2$
   d) $1101_2 - 1011_2$
   e) $1001_2 - 0111_2$
   f) $1100_2 - 1001_2$

12. Multiply the following 3-bit numbers:
   a) $100_2 * 010_2$
   b) $111_2 * 010_2$
   c) $110_2 * 011_2$
   d) $101_2 * 011_2$
   e) $110_2 * 101_2$
   f) $101_2 * 101_2$

13. Calculate:
    a) $150_8 + 75_8$
    b) $532_8 - 174_8$
    c) $423_8 + 326_8$
    d) $423_8 - 326_8$
    e) $56712_8 + 24415_8$
    f) $56712_8 - 24415_8$
    g) $1023_8 + 424_8$
    h) $1023_8 - 424_8$
    i) $354_8 + 622_8$
    j) $1103_8 - 243_8$

14. Calculate:
    a) $36_{16} + 4D_{16}$
    b) $4D_{16} + DE_{16}$
    c) $DE_{16} - 7B_{16}$
    d) $7B_{16} + 6A_{16}$
    e) $6A_{16} + 85_{16}$
    f) $DF_{16} - 11_{16}$
    g) $BD_{16} - 11_{16}$
    h) $BA3_{16} + 5DE_{16}$

-End of Homework-

SCAN ME FOR ANSWERS

FINAL EXAMINATION QUESTION SAMPLE

1. Complete the following in terms of data organization that stated in bracket.
   a) 24 bits (nibbles)
   b) 5 words (bits)
   c) 128 bytes (double words)

2. Convert the following:
   a) 11100011_2 to decimal
   b) 62_8 to binary
   c) 444_8 to hexadecimal
   d) 2017_{10} to octal
   e) 33_{10} to binary

3. Calculate the following:
   a) 1101_2 + $DAD1_{16}$ (Give your answer in octal)
   b) 246_8 – 59_{10} (Give your answer in hexadecimal)

-End of Final Examination Question Sample-

SCAN ME FOR ANSWERS

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FEEDBACK

"This book is one of the mathematical references that covers a solid understanding of the number system. In this book, we will explore the binary, octal, hexadecimal and decimal number systems as well as the addition, subtraction and multiplication operations of the number system. This book also includes easy - to -understand explanations and exam -shaped questions."

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MATHEMATICAL COMPUTING