HKOI Training

$ami \sim wkc$

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Lecture 01
An introduction to problem solving and programming in C

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Problem solving - Maths

- Understand the problem

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Problem solving - Maths

- Understand the problem
- Discover new properties, lemmas, theorems etc.

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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- Understanding what it is

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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- Understanding how to use

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Problem solving - Maths

- Understand the problem
- Discover new properties, lemmas, theorems etc.
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- Understanding how to use
- Understanding why it is true

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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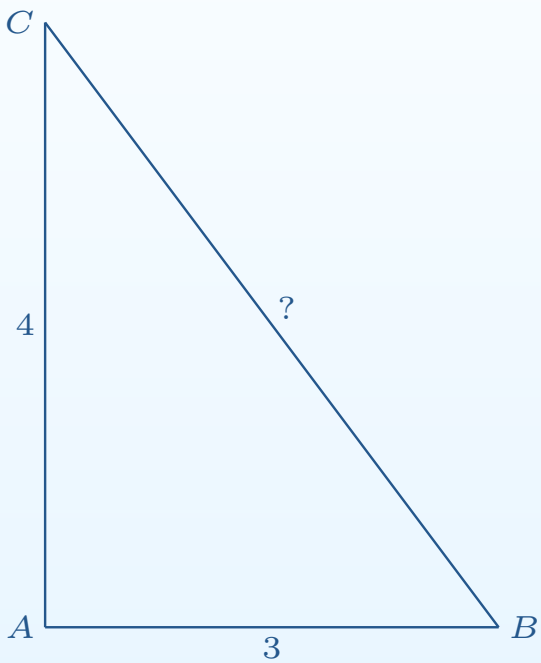
Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Example - Pythagoras theorem



Find BC if BC is an integer.

Find positive integer solutions to the equation $a^2 + b^2 = c^2$.

Is there any relation between the above two problems?

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Theorem (Pythagoras). *If $a^2 + b^2 = c^2$, there is a right triangle with sides a,b,c.*

For each right triangle, sum of square of legs is equal to square of the hypotenuse.

In particular, if a right triangle has integer sides, the sides are a solution to the equation.

Example - Pythagoras theorem (Cont'd)

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

What is the Pythagoras theorem?

Example - Pythagoras theorem (Cont'd)

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

What is the Pythagoras theorem?

- It relates the sides of a right triangle.
- It relates each solution with a right triangle.

Example - Pythagoras theorem (Cont'd)

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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How can you use it to find BC?

Example - Pythagoras theorem (Cont'd)

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

What is the Pythagoras theorem?

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How can you use it to find BC?

The theorem said, $(3, 4, BC)$ is one of the solutions.

There are a few possibilities:

Example - Pythagoras theorem (Cont'd)

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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1. $b = 3, c = 4$ and $a = BC$
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4. $a = 4, c = 3$ and $b = BC$
5. $a = 3, b = 4$ and $c = BC$
6. $a = 4, b = 3$ and $c = BC$

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Are they all possible?

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Are they all possible? NO!

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Example - Pythagoras theorem (Cont'd)

Let's check all of them:

1. putting $b = 3, c = 4$ and $a = BC$, we have
   $BC^2 + 3^2 = 4^2 \iff BC^2 = 16 - 9 = 7 \implies BC = \sqrt{7}$ (?)

2. putting $b = 4, c = 3$ and $a = BC$, we have $BC^2 = -7$, impossible

$\vdots$

Finally, putting $a = 4, b = 3$ and $c = BC$, we have $BC^2 = 25 \implies BC = 5$.

We have the two possible values for BC, $\sqrt{7}$ and 5.

Since $\sqrt{7}$ is not an integer, BC must be 5.[1]

[1] "When you eliminate the impossible, whatever remains–however improbable–must be the truth."

Example - Pythagoras theorem (Cont'd)

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Why is the Pythgoras theorem true?

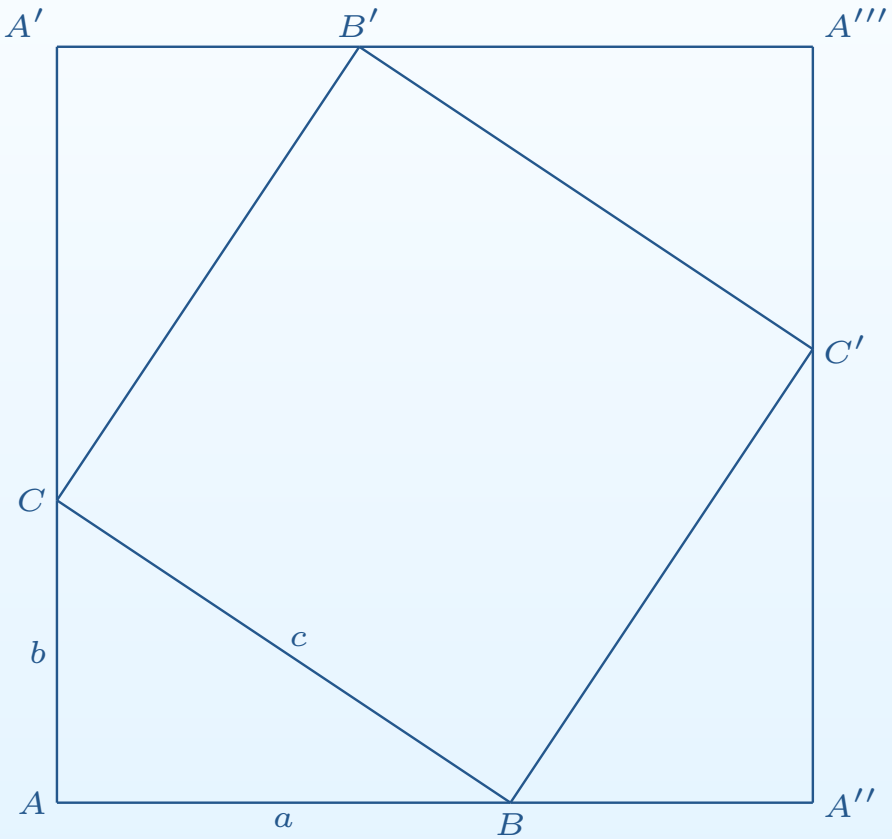
Example - Pythagoras theorem (Cont'd)

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Why is the Pythgoras theorem true?



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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Proof. Rotate the given right triangle to product the figure.

Area of the whole figure is $(a+b)^2 = a^2 + 2ab + b^2$

On the other hand, it is the sum of area the smaller square and four triangles.

Area of $\triangle ABC$ is $\frac{1}{2}ab$, so does the other three triangles.

Area of the smaller square is c^2

Hence, $a^2 + 2ab + b^2 = 4\left(\frac{1}{2}ab\right) + c^2 \iff a^2 + b^2 = c^2$. □

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Remainder/Modulus

Definition. *Let m, n be two integers with $n \neq 0$,*

$m \bmod n$ is defined as the remainder when m is divided by n

For example, $7 \bmod 3 = 1$ and $107 \bmod 8 = 3$

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Let $n = 7\underbrace{201120112011\ldots20112011}_{2000-digits}$ be an 2001-digit number.

Find $n \bmod 3$ and $n \bmod 11$.

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Hints: Consider digit sum and alternating digits sum.

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Find $n \bmod 3$ and $n \bmod 11$. (Joking!?)
Hints: Consider digit sum and alternating digits sum.

Theorem (Divisibility of 3 and 11)**.** *Let m be an integer,*
S be its digit sum and A be its alternating digit sum,
then $m \bmod 3 = S \bmod 3$ and $m \bmod 11 = A \bmod 11$

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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As a demonstration,
Alternating digit sum of 10947 : 7 - 4 + 9 - 0 + 1 = 13 (adding from the rightmost digit)
$10947 = 11 \cdot 995 + 2$ hence $10947 \bmod 11 = 2$. Also, $13 \bmod 11 = 2$.

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Digit sum of 1234 : 1 + 2 + 3 + 4 = 10 (Easy)
$1234 = 3 \cdot 411 + 1$ hence $1234 \bmod 3 = 1$. Also $10 \bmod 3 = 1$.

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Digit sum of 1234 : 1 + 2 + 3 + 4 = 10 (Easy)

$1234 = 3 \cdot 411 + 1$ hence $1234 \bmod 3 = 1$. Also $10 \bmod 3 = 1$.

We will come back to the proof when we have enough maths knowledge. (Number theory)

Problem solving - Computer

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

An extra tool - computer.

Problem solving - Computer

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

An extra tool - computer.

It can do task very fast.

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Problem solving - Computer

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NO ANY MORE.

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Problem solving - Computer

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Guess number

n is a five-digit square number, whose digits are 2 and 9 only. Find all possible n.

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Let $n = \overline{abc}^2$ and $n = \overline{ABCDE}$

1. The unit digit must be 9 and $c = 3, 7$

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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1. The unit digit must be 9 and $c = 3, 7$ (Why?)
2. The tenth's digit must be 2 (Key step!)
3. $b = 2, 7$ (Why?)
4. Since $323^2 > 320^2 = 102400$, we have $a = 1, 2$

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

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2. Check the numbers one by one to see if its digits are 2 and 9 only.

Mathematical way: (only idea are listed here)
Let $n = \overline{abc}^2$ and $n = \overline{ABCDE}$

1. The unit digit must be 9 and $c = 3, 7$ (Why?)
2. The tenth's digit must be 2 (Key step!)
3. $b = 2, 7$ (Why?)
4. Since $323^2 > 320^2 = 102400$, we have $a = 1, 2$
5. If $a = 2$ then $2 < A < 9$, impossible

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Guess number

n is a five-digit square number, whose digits are 2 and 9 only. Find all possible n.

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Introduction
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- Pythagoras theorem
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Programming in C

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7. $n = 29929 = 173^2$

We will come back to step 2 and 3 when we have enough maths knowledge. (Number theory)

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

End

Guess number (Cont'd)

Does the following computer related idea work?

- Ask the computer to solve it.
- Ask the computer to explain the previous questions.

Guess number (Cont'd)

Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

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Does the following computer related idea work?

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Introduction
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- Pythagoras theorem
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- PCIMC-09-H5-Q16

Programming in C

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Introduction
- Problem solving - Maths
- Pythagoras theorem
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- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

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Introduction
- Problem solving - Maths
- Pythagoras theorem
- Remainder/Modulus
- Problem solving - Computer
- PCIMC-09-H5-Q16

Programming in C

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Prime checking example, to check whether 1001 is a prime.

1. Set $z = 1$ at first,
2. Starting from 2 to 1000 : if a number divide 1001, change z to 0.
3. If z is 1 then 1001 is a prime, otherwise it is a composite.

Computer can follow the above instruction and do each step one by one repeatedly.

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

Programming in C

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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What can a computer do?

- Arithmetic - Addition, subtraction, multiplication, quotient, modulus and division

Introduction

Programming in C

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- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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What can a computer do?

- Arithmetic - Addition, subtraction, multiplication, quotient, modulus and division
- Store value - Putting a value into some named boxes

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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What can a computer do?

- Arithmetic - Addition, subtraction, multiplication, quotient, modulus and division
- Store value - Putting a value into some named boxes
- Change value - Change a value to another value in a given boxes
- Store action - Record all steps for computing $\sqrt{x}$ etc.

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

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- Recognize a value - The integer 1001 , π , “Your Name here” etc.

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

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For those who interested finding square root without calculator, read wiki page

Linguistic matter of human language

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

Although we list out the steps for checking 1001 is a prime or not in English,

a computer cannot understand our human language.

Our language has so many grammar rules, even ourselves would feel confusing sometimes.

Linguistic matter of human language

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

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Consider the followings:

1. He looks so blue.

2. The second unique child of the God.

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Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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The first sentence has two meaning according to different meaning of blue.
The second sentence is self-contradicting.

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

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Consider the followings:

1. He looks so blue.

2. The second unique child of the God.

The first sentence has two meaning according to different meaning of blue.
The second sentence is self-contradicting.
Computer cannot distinguish the meanings in these situations.

Programming Language - Computer’s language

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer’s language
- C Syntax - Arithmetic

End

Therefore, we need a simpler language that can describe the things for a computer can do.

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

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These kind of languages is called a *programming language*.

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

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Programming Languages:

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

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Programming Languages:

C, C++, Pascal, Common Lisp, Go, Prolog, ML, PHP, MATHLAB, Assembly, Machine Code, ...

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

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Introduction

Programming in C

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Introduction

Programming in C

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- Linguistic matter of human language
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Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
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- C Syntax - Arithmetic

End

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Introduction

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- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

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Syntax is the term for Programming Languages' grammar rules and punctuation marks.

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

C Syntax - Arithmetic

Addition	+
Subtraction	-
Multiplication	*
Quotient	/
Modulus	%
Open Bracket	(
Close Bracket	)

Unlike mathematics, the multiplication symbol is a star * in C.

Therefore, the expression $1 + 2 \times 3$ is written as $1 + 2 * 3$ in C.

Introduction

Programming in C

- What can a computer do?
- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

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Introduction

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Obviously, you cannot type fraction easily in a computer.

$\frac{3+x}{a-2}$ must be written as $(3 + x)/(a - 2)$ in C.

Introduction

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- Linguistic matter of human language
- Programming Language - Computer's language
- C Syntax - Arithmetic

End

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Introduction

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- Linguistic matter of human language
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However many spaces are there, $3 + x/a - 2$ and $3 + x \ / \ a - 2$ are the same.

Therefore, we need to be strict in the rules that first multiplication then addition.

End