Lecture Notes for Lecture 4 of CS 5001 (Foundations of CS) for the Fall, 2018 session at the Northeastern University Silicon Valley Campus.

Decision Making, Conditional Processing, and Repetition

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Lecture 3 Review

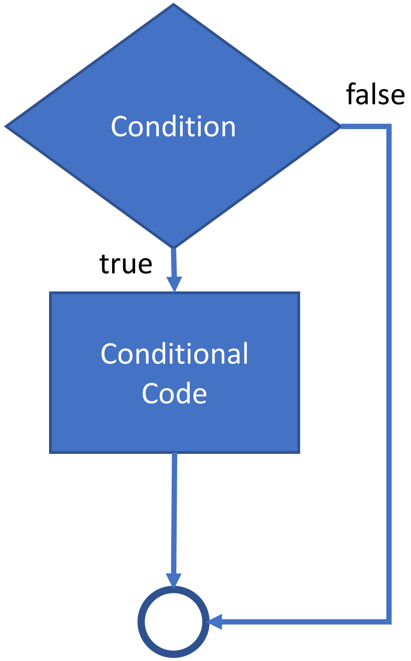
- A C function consists of
    - a documentation block with purpose, parameters, and return type descriptions
    - a prototype including return type and formal parameter declarations
    - a function body that implement the business logic of the function
- Formal parameters are local variables set when the function is called.
- Function then performs its operations and returns a return type value.
- A function with *void* return type returns no value, and with *void* parameter list accepts no arguments.
- Functions can access parameters and other locally declared variables, and global variables that are shared among functions.
- Functional decomposition divides a program among functions that encapsulate business logic and are easier to design and maintain.
- C runtime initializes the program, calls main function, and terminates the program when main function returns.

Decision Making

- Program logic often depends on evaluating conditions during a computation and performing different sequences of operations depending on the results of the evaluation.
- C language provides control statements that use boolean values to determine sequence of statements to perform.
- Boolean values are often the result evaluating expressions involving comparison and logical operators.
- Types of control statements:
  - Conditional
  - Choice
  - Repeated

Conditional Processing

- The simplest conditional control statement uses a boolean value to determine whether to execute statements if the value is *true*. In C, this is know as an “if” statement.



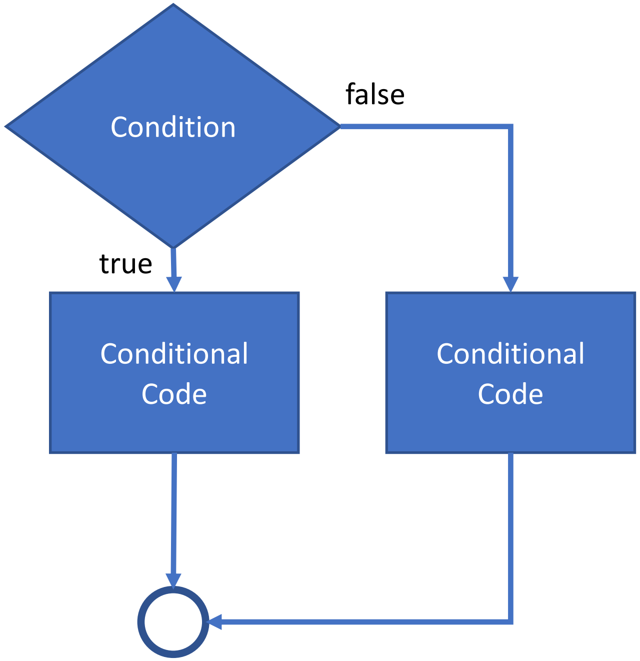
```
if (boolean-condition) {
    conditional statements
}
```

Example: add surtax to water bill if usage exceeds limit.

```
if (waterUsage > usageLimit) {
    waterBill += surtax*waterBill;
}
```

Conditional Processing

- The conditional control statement can include optional statements to execute if the boolean value is false. In C, this is know as an “if-then-else” statement.



```
If (*boolean-condition*) {
   *conditional statements*
} else {
   conditional statements
}
```

Example: add surtax to water bill if usage exceeds usage limit, else apply discount for conservation.

```
If (waterUsage > usageLimit) {
   waterBill += surtax*waterBill;
} else {
   waterBill -= discount*waterBill;
}
```

Conditional Processing

- Example: Compute water bill with adjustments

```
#include <stdio.h>
#include <stdlib.h>

/**  15% surtax for excess use */
const float surtax = 0.15;

/** 10% discount for conservation */
const float discount = 0.10;

/** Maximum usage triggers surtax */
const float usageLimit = 125.0;
```

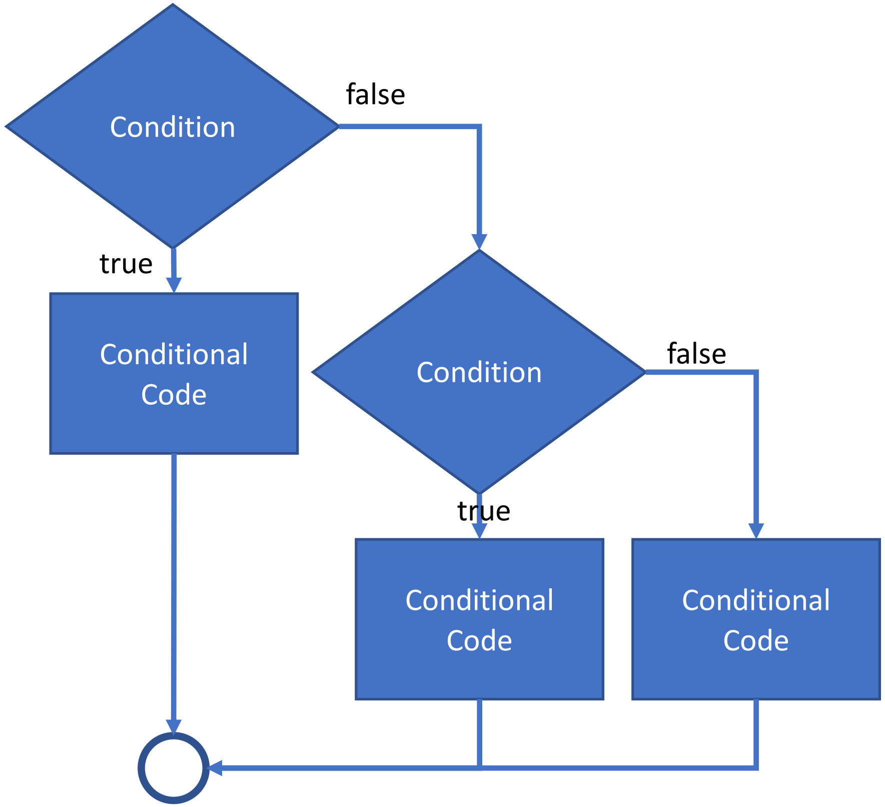
Conditional Processing

- Example: Compute water bill with adjustments

```
/**
 * Adjust water bill based on water usage.
 * @param waterBill original water bill
 * @param usage water usage
 * @ return adjusted water bill based on usage limit
 */
float adjustWaterBill(float waterBill, float usage) {
    if (usage > usageLimit) {  // apply surtax if exceeded limit
        waterBill += surtax * waterBill;
    } else {  // apply discount for conservation
        waterBill -= discount * waterbill;
    }
    return waterBill;
}
```

Conditional Processing

- Control statements can contain other control statements. One style is the cascaded control statement. In C this is known as an “if-then-else-if” statement



```
If (boolean-condition) {
   conditional statements
} else if (boolean-condition) {
   conditional statements
} else {  // optional
   conditional statements
}
```

Example: add surtax to water bill if usage exceeds usage limit, else apply discount for usage below conservation limit

```
If (waterUsage > usageLimit) {
   waterBill += surtax*waterBill;
} else if (waterUsage < conservationLimit) {
   waterBill -= discount*waterBill;
} else {
   // no change to bill
}
```

Conditional Processing

- Example: Compute water bill with adjustments

```
#include <stdio.h>
#include <stdlib.h>

/**  15% surtax for excess use */
const float surtax = 0.15;

/** 10% discount for conservation */
const float discount = 0.10;

/** Maximum usage triggers surtax */
const float usageLimit = 125.0;

/** Maximum usage for discount */
const float conservationLimit = 85.0;
```

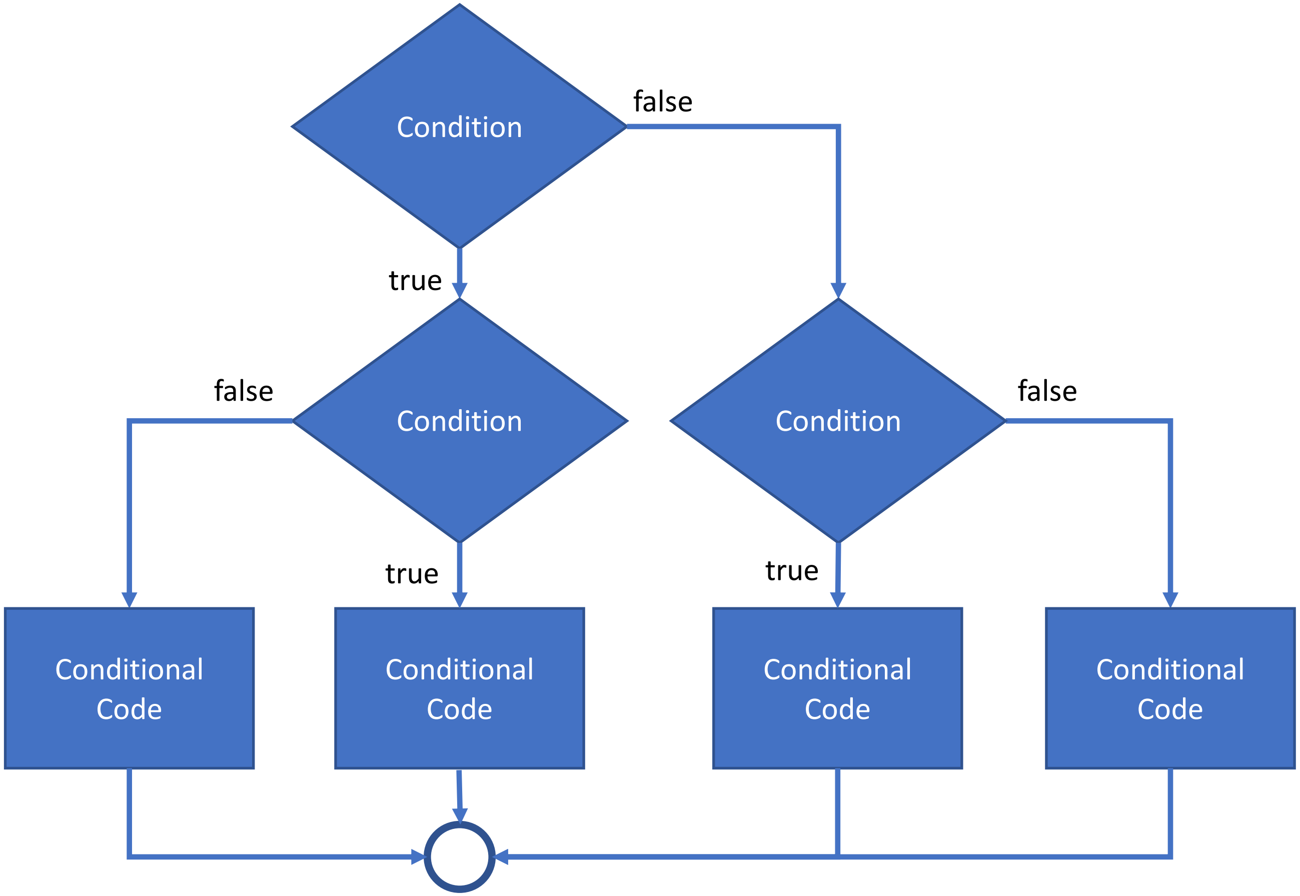
Conditional Processing

- Example: Compute water bill with adjustments

```
/**
 * Adjust water bill based on water usage.
 * @param waterBill original water bill
 * @param usage water usage
 * @ return adjusted water bill based on usage limit
 */
float adjustWaterBill(float waterBill, float usage) {
     if (usage > usageLimit) {  // apply surtax if exceeded limit
             waterBill += surtax * waterBill;
     } else if (usage < conservationLimit) {  // apply discount for conservation
             waterBill -= discount * waterbill;
     }
     return waterBill;
}
```

Conditional Processing

- Another nested control statement is when a second decision is needed on both sides. This is known as a “decision tree.”



Conditional Processing

- Example: If water bill is delinquent, over-use penalties double and conservation discounts are halved.

```
#include <stdbool.h>
#include <stdio.h>
#include <stdlib.h>

/**  15% surtax for excess use */
const float surtax = 0.15;

/** 10% discount for conservation */
const float discount = 0.10;

/** Maximum usage triggers surtax */
const float usageLimit = 125.0;

/** Maximum usage for discount */
const float conservationLimits= 85.0;
```

Conditional Processing

- Example: If water bill is delinquent, over-use penalties double and conservation discounts are halved.

```
/**
 * Adjust water bill based on water usage.
 * @param waterBill original water bill
 * @param usage water usage
 * @param delinquent true if bill is delinquent
 * @ return adjusted water bill based on usage limit
 */
float adjustWaterBill(float waterBill, float usage, bool delinquent) {
    if (usage > usageLimit) {  // apply surtax if exceeded limit
        if ( delinquent) {
            waterBill += 2 * surtax * waterBill;
        } else {
            waterBill += surtax * waterBill;
        }
    }
```

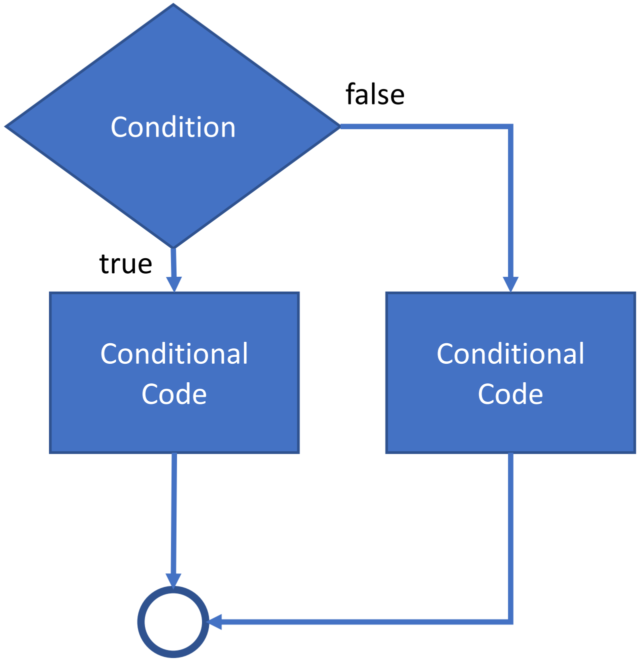
Conditional Processing

- Example: If water bill is delinquent, over-use penalties double and conservation discounts are halved.

```
    else if (usage < conservationLimit) {  // apply discount for conservation
        if (delinquent) {
            waterBill -= discount/2 * waterBill;
        } else {
            waterBill -= discount * waterBill;
        }
    } else {
        if (delinquent) {   // apply surtax if only late
            waterBill += 2 * surtax * waterBill;
        }
    }
    return waterBill;
}
```

Conditional Processing

- Conditional expression has the same role as conditional statement, but can be used in an expression. C language supports conditional expressions



(*boolean-condition*) ? expr : expr

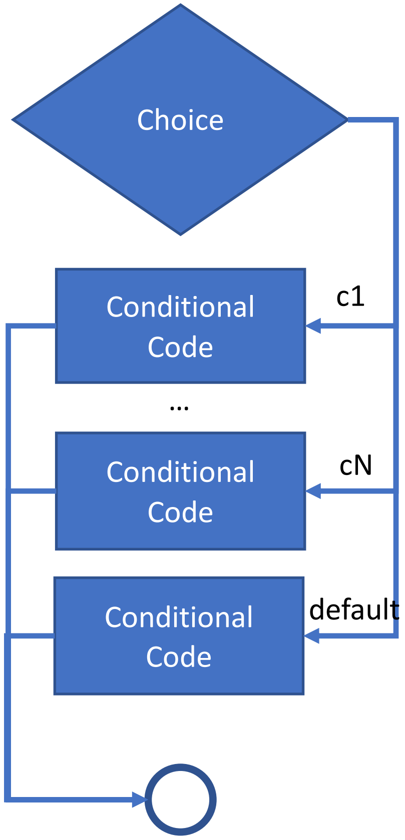
Both expr must be of conforming types.

Example: implement min(x,y) function:.

(x < y) ? x : y

Conditional Processing

- The choice control statement uses an integral value to select a sequences of statements. In C, this is known as a “switch” statement, and switch selectors must be integral constants.



```
switch (integral-value) {
case c1:
   conditional statements
   break;
case c2:
   conditional statements
   break;
…
case cN:
   conditional statements
   break;
default:
   conditional statements
   break;
}
```

Conditional Processing

- Example: Perform specified arithmetic operation

```
/**
 * Perform arithmetic operation: +, -, *, /.
 * @param v1  the first operand
 * @param v2 the second operand
 * @param op the operator
 * @ return the arithmetic result or NAN if unknown operator
 */
float math(float v1, float v2, char op) {
    float result;
    switch (op) {
    case ‘+’:    // addition
          result = v1 + v2;
          break;
```

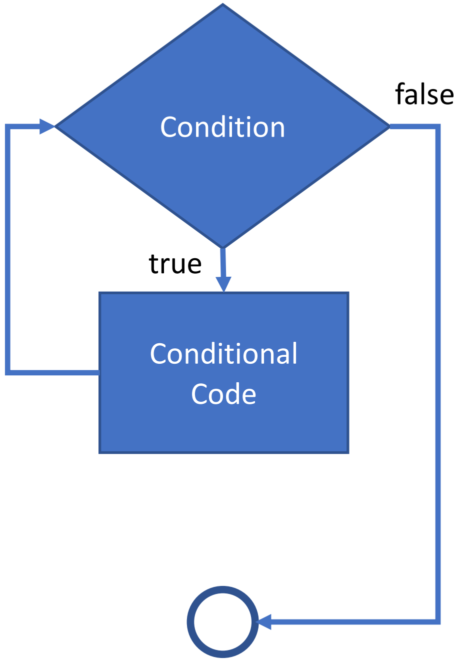
Conditional Processing

- Example: Perform specified arithmetic operation

```
        case ‘-’:    // subtraction
                result = v1 - v2;
                break;
        case ‘*’:    // multiplication
                result = v1 * v2;
                break;
        case ‘/’:    // division
                result = v1 / v2;
                break;
        default:    // unknown operator
                result = NAN;
        }
        return result;
    }
```

Repetition

- The repeated control statement repeats the statement body while a boolean condition remains true. In C repeated control statements include for, while, and do-while.



Repeated control structures

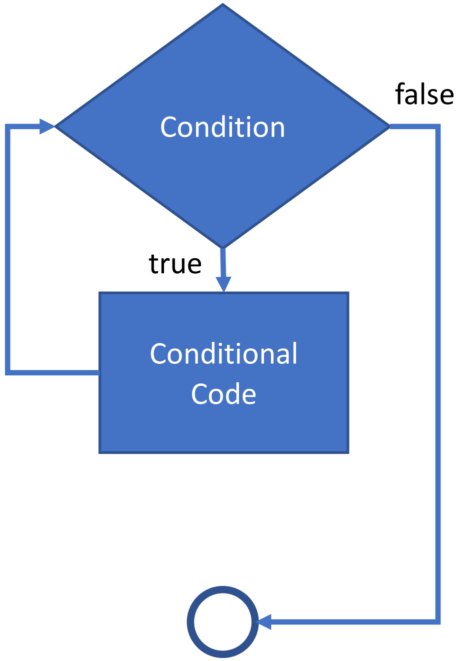
```
while(boolean-condition) {
    conditional statements
}

for (init; boolean-condition; re-init) {
    conditional statements
}

do {
    conditional statements
} while(boolean-condition);
```

Repetition

- Anatomy of while loop



```
while (boolean-condition) {
        conditional-statements;
}
```

- initialization of loop variables and condition done before loop is executed
- *boolean-condition* is evaluated at the beginning of each iteration; conditional code run if condition is true
- *conditional code* is responsible for terminating loop based by changing state of boolean-condition

Repetition

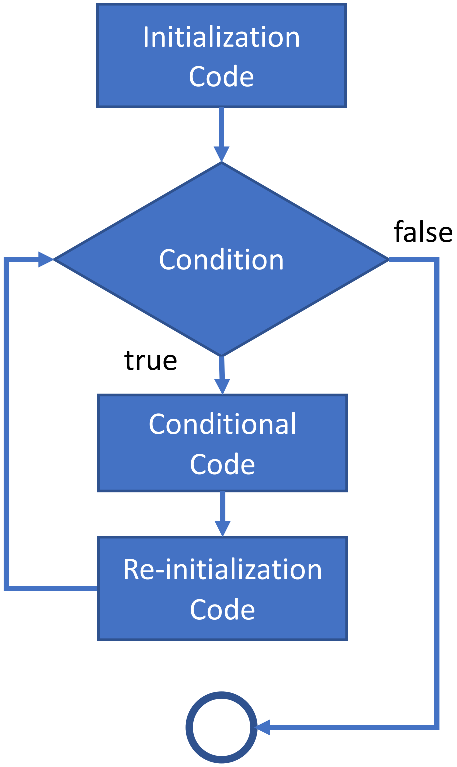
- Example: Echo characters from input to output

```
#include <stdio.h>

/**
 * Echo characters from input to output
 */
int main(void) {
    int ch = getchar();
    while (ch != EOF) {
        putchar(ch);
        ch = getchar();
    }
}
```

Repetition

- Anatomy of for loop



for (*init*; *boolean-condition*; *re-init*) {
        conditional-statements;
}

- *initialization* code executed only once; declare and initialize loop control variables
- *boolean-condition* is evaluated at the beginning of each iteration; conditional code run if condition is true
- *re-initialization* code is performed after conditional code runs, but before *boolean-condition* is re-evaluated.

Repetition

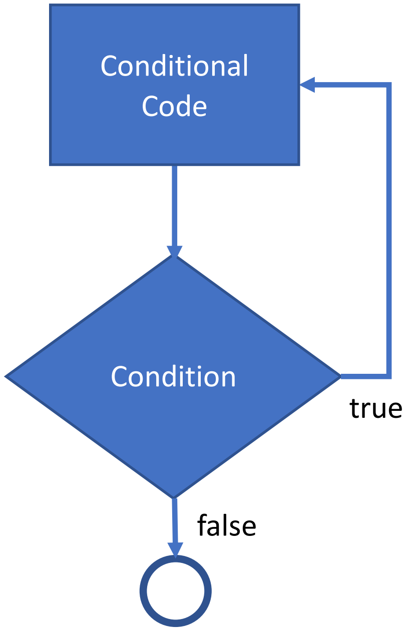
- Example: Printing lower-case letters and their alphabets

```
#include <stdio.h>

/**
 * Print lower-case characters of the alphabet
 */
int main(void) {
    // loop over lower case letters
    for (char ch = 'a'; ch <= 'z'; ch++) {
            printf("'%c':  code: %x\n", ch, ch);
    }
}
```

Repetition

- Anatomy of do-while loop



do {
        conditional-statements;
} while (*boolean-condition*);

- initialization of loop variables and condition done before loop is executed
- conditional code run once before *boolean-condition* evaluated at the end of each iteration; conditional repeats if condition is true
- *conditional code* is responsible for terminating loop based by changing state of boolean-condition

Repetition

- Example: Square root by successive approximation

```
#include <stdio.h>
#include <math.h>

/**
 * Uses Babylonian or Hero’s method to approximate the non-negative
 * real square root of a non-negative real number.
 *
 * The idea is that if x is an overestimate to the square root of a non-negative
 * real number s then (s/x) is an underestimate, so the average of these two
 * numbers may reasonably be expected to provide a better approximation.
 * @param n the number to operate on
 * @param epsilon the precision required
 * @return the square root to the specified precision
 */
```

Repetition

- Example: Square root by successive approximation

```
double mySqrt(double n, double epsilon) {
    if (n < 0.0) {      // special case square root of negative number
        return NAN;
    }
    if (n == 0.0) {    // special case 0 to avoid divide by 0
        return 0.0;
    }
    double guess = n;     // guess value of n as sqrt of n initially
    double lastGuess;
    do {
        lastGuess = guess;    // save last guess and make new one
        guess = (lastGuess + n/lastGuess)/2.0;    // new guess bounds from above
    } while (lastGuess - guess > epsilon);       // done if guesses converged
    return guess;
}
```

Repetition

- Example: Square root by successive approximation

```
/**
 * This function tests square root function
 */
int main(void) {
    double n, sqrtN, epsilon = 1.0e-6;
    n = 0.0;     sqrtN = mySqrt(n, epsilon);     printf("sqrt(%lf): %lf\n", n, sqrtN);
    n = 0.5;     sqrtN = mySqrt(n, epsilon);     printf("sqrt(%lf): %lf\n", n, sqrtN);
    n = 1.0;     sqrtN = mySqrt(n, epsilon);     printf("sqrt(%lf): %lf\n", n, sqrtN);
    n = 2.0;     sqrtN = mySqrt(n, epsilon);     printf("sqrt(%lf): %lf\n", n, sqrtN);
    n = 4.0;     sqrtN = mySqrt(n, epsilon);     printf("sqrt(%lf): %lf\n", n, sqrtN);
    n = 125348.0;   sqrtN = mySqrt(n, epsilon);     printf("sqrt(%lf): %lf\n", n, sqrtN);
}
```