Compilers Lab
COE – 406

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262/CO/12
COE – 1

Index

1) Assembler for 8085 [JavaScript, NodeJS]

index.js

```
'use strict';

var asm = {};

const iSet = require('./instructionSet');

/* Assembles the given code into machine code */
asm.assemble = (code, showAddress) => {
  showAddress = showAddress || false;
  let labels = {};
  let startWith = 0;
  let assembledCode = [];

  /* Preprocessing : Decomment */
  let codeLines = asm.decomment(code).split('\n').map(cl => cl.trim());

  /* First Pass: Get all labels in labels obj */
  codeLines.reduce((startWith, codeLine) => {
    if(asm.isORGDirective(codeLine)) {
      startWith = asm.getORGLocation(codeLine);
    } else {
      if(asm.isLabel(codeLine)) {
        labels[asm.getLabel(codeLine)] = asm.toHex(startWith);
      }
      startWith += asm.getInstructionSize(codeLine);
    }
    return startWith;
  }, startWith);

  // console.log(labels);

  /* Second Pass: Expand mnemonics, replace label tags with actual line number
*/
  startWith = -1;
  codeLines.forEach((codeLine, index) => {
    if(asm.isORGDirective(codeLine)) {
      startWith = asm.getORGLocation(codeLine) - 1;
    } else {
      let iFormat = asm.sanitize(codeLine);
      let operands = asm.getInstructionOperands(codeLine);
      let lastOperand = operands[operands.length - 1];
      /* First step for each instruction */
      assembledCode.push({ address: asm.toHex(++startWith), code:
iSet[iFormat].code });

      switch(asm.getInstructionSize(codeLine)) {
        case 2: assembledCode.push({ address: asm.toHex(++startWith), code:
lastOperand }); break;
        case 3:
          lastOperand = (asm.isLabelInstruction(codeLine) && lastOperand in labels)
? labels[lastOperand] : lastOperand;
          assembledCode.push({ address: asm.toHex(++startWith), code:
lastOperand.slice(-2) });
          assembledCode.push({ address: asm.toHex(++startWith), code:
lastOperand.slice(-4, -2) });
          break;
      }
    }
  });

  return assembledCode.reduce((string, value) => string += ((showAddress?
(value.address + ' ') : '') + value.code + '\n'), '');
};

/* Returns the size (in bytes) of the instruction */
asm.getInstructionSize = codeLine => {
  if(!asm.isValidInstruction(codeLine)) {
    throw new Error('Instruction "' + codeLine + '" doesn\'t match to any
instruction');
  }
  return iSet[asm.sanitize(codeLine)].size;
};

/* Converts a number to 'data' or 'address' tag which is used in formal instruction
format */
asm.numberToTag = codeLine => {
  let operands = asm.getInstructionOperands(codeLine);
  if(operands.length > 0) {
    if(asm.isDataInstruction(codeLine)) {
      codeLine = codeLine.replace(operands[operands.length - 1], 'data');
    } else if(asm.isLabelInstruction(codeLine)) {
      codeLine = codeLine.replace(operands[operands.length - 1], 'address');
    }
  }
  return codeLine;
};
```

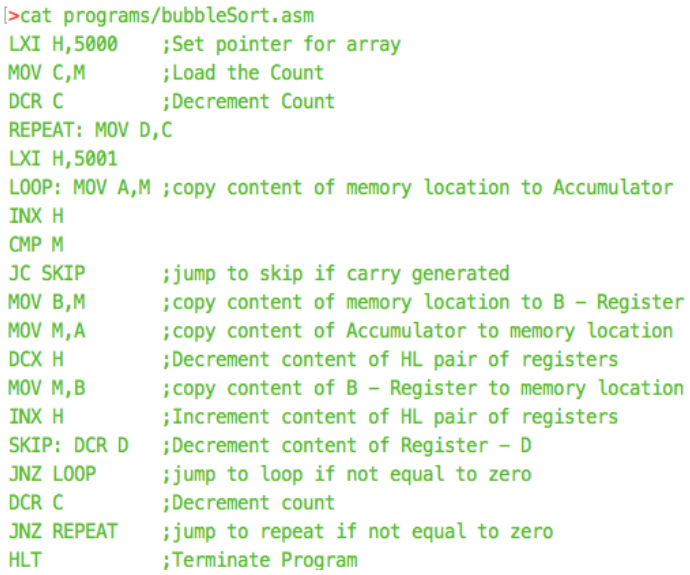
```
/* Remove comments, anything starting with ; */
asm.decomment = code => code.replace(/(;.*)/g, '').trim();

/* Tells whether given line has a label to it */
asm.isLabel = codeLine => codeLine.split(' ')[0].endsWith(':');

/* Returns label of a code line with a label to it */
asm.getLabel = codeLine => codeLine.split(' ')[0].slice(0, -1);

/* Checks whether given code line is a DB directive */
asm.isDBDirective = codeLine => codeLine.trim().startsWith('# DB');

/* Checks whether given code line is an ORG directive */
asm.isORGDirective = codeLine => codeLine.trim().startsWith('# ORG');

/* Checks whether given code line is an DB directive */
asm.isDBDirective = codeLine => codeLine.trim().startsWith('# DB');

/* Checks validity of code line based on instruction set*/
asm.isValidInstruction = codeLine => asm.sanitize(codeLine) in iSet;

/* Removes label from a given code line, if any */
asm.removeLabel = codeLine => codeLine.replace(/[a-zA-Z]+:/g, '').trim();

/* Returns the decimal location where an ORG directive instruction points to */
asm.getORGLocation = orgLine => parseInt(orgLine.replace('# ORG', '').trim(),
16);

/* Returns array of data to be stored as per DB Directive */
asm.getDBOperands = dbLine => dbLine.replace('# DB', '').split(',').map(e =>
e.trim());

/* Returns the mnemonic of main instruction */
asm.getInstructionName = codeLine => codeLine.split('
')[(asm.isLabel(codeLine) ? 1 : 0)];

/* Returns upper case hex string of 4 digits for given decimal number */
asm.toHex = decimalNumber => ("000" +
decimalNumber.toString(16).toUpperCase()).slice(-4);

/* Converts a code line to formal instruction format as per Instruction Set */
asm.sanitize = codeLine =>
asm.labelToTag(asm.numberToTag(asm.removeLabel(codeLine))).trim();
```

```
/* Checks whether given instruction belongs to ones which have immediate data
operand */
asm.isDataInstruction = codeLine =>
iSet.dataInstructions.indexOf(asm.getInstructionName(codeLine)) > -1;

/* Checks whether given instruction belongs to ones which have an
address/label operand */
asm.isLabelInstruction = codeLine =>
iSet.labelInstructions.indexOf(asm.getInstructionName(codeLine)) > -1;

/* Converts a label to 'address' tag which is used in formal instruction format.
 * TODO: labels can also point to data, say by using EQU */
asm.labelToTag = codeLine => asm.isLabelInstruction(codeLine) ?
codeLine.replace(codeLine.split(' ').slice(-1), 'address') : codeLine;

/* Returns array of operands of an instruction */
asm.getInstructionOperands = codeLine =>
asm.removeLabel(codeLine).replace(asm.getInstructionName(codeLine),
'').split(',').map(e => e.trim());

module.exports = asm;
```

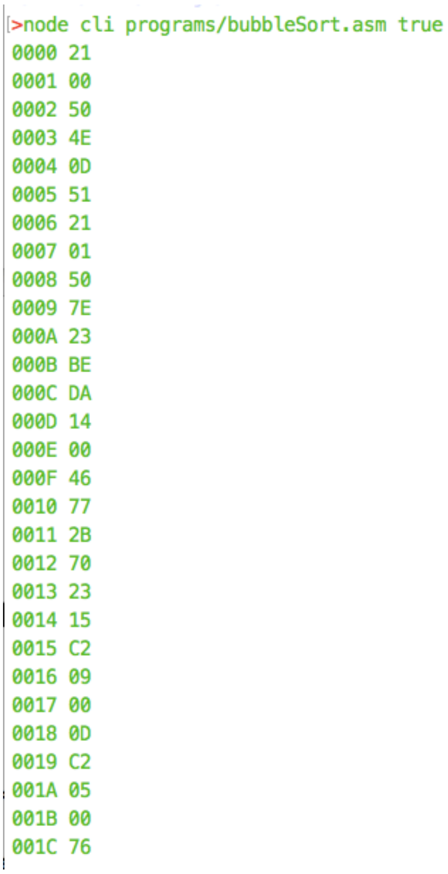
instructionSet.js (Contains entire instruction set of 8085 and metadata)

```
'use strict';

module.exports = {
  dataInstructions: ['ACI', 'ADI', 'ANI', 'MVI', 'CPI', 'ORI', 'SBI', 'SUI', 'XRI', 'LXI'],
  labelInstructions: ['JMP', 'JC', 'JM', 'JNC', 'JNZ', 'JP', 'JPE', 'JPO', 'JZ', 'CALL', 'CC',
'CM', 'CNC', 'CNZ', 'CP', 'CPE', 'CPO', 'CZ', 'LDA', 'LHLD', 'SHLD', 'STA'],
  'ACI data': {
    'size': 2,
    'code': 'CE',
    'desc': 'Add with Carry Immediate'
  },
  'ADC A': {
    'size': 1,
    'code': '8F',
    'desc': 'Add with Carry'
  },
…
  'XTHL': {
    'size': 1,
    'code': 'E3',
    'desc': 'Exchange stack Top with HL'
  }
};
```

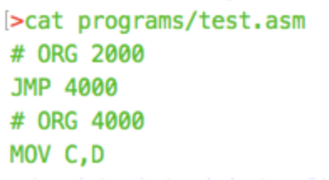
Output



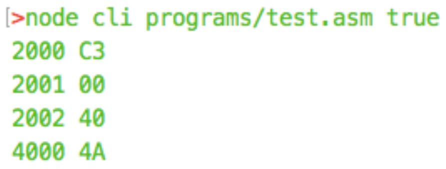
```
[>cat programs/bubbleSort.asm
LXI H,5000    ;Set pointer for array
MOV C,M       ;Load the Count
DCR C         ;Decrement Count
REPEAT: MOV D,C
LXI H,5001
LOOP: MOV A,M ;copy content of memory location to Accumulator
INX H
CMP M
JC SKIP       ;jump to skip if carry generated
MOV B,M       ;copy content of memory location to B - Register
MOV M,A       ;copy content of Accumulator to memory location
DCX H         ;Decrement content of HL pair of registers
MOV M,B       ;copy content of B - Register to memory location
INX H         ;Increment content of HL pair of registers
SKIP: DCR D   ;Decrement content of Register - D
JNZ LOOP      ;jump to loop if not equal to zero
DCR C         ;Decrement count
JNZ REPEAT    ;jump to repeat if not equal to zero
HLT           ;Terminate Program
```



```
[>node cli programs/bubbleSort.asm true
0000 21
0001 00
0002 50
0003 4E
0004 0D
0005 51
0006 21
0007 01
0008 50
0009 7E
000A 23
000B BE
000C DA
000D 14
000E 00
000F 46
0010 77
0011 2B
0012 70
0013 23
0014 15
0015 C2
0016 09
0017 00
0018 0D
0019 C2
001A 05
001B 00
001C 76
```



```
[>cat programs/test.asm
# ORG 2000
JMP 4000
# ORG 4000
MOV C,D
```



```
[>node cli programs/test.asm true
2000 C3
2001 00
2002 40
4000 4A
```

2) Context Free Grammar for subset of C

Start

<start> -> <pre-processor-directives> <function-declarations> <main-function> FUNCTION

<pre-processor-directives> -> #include<L> | #include"S" | #define <identifier> M| typdef <type><identifier>;

L -> A-Za-z

M -> [0-9]+ | ".*"

S -> \S*

<main-function> -> int main(Z)S

Z -> void | intI, char*I[] | int I,char**

<function-declarations> -> FUNCTIONDEC

Types

<types> -> P | P*

P -> int | char | float | double | void

Identifier

<identifier> -> [a-zA-Z_$][a-zA-Z_$0-9]*

Expressions

E - Expression

<expression> -> <identifier> | <number> |E+F | E-F

F -> F*G | F/G

G -> (E)

Declaration Expressions

<declaration> -> <type> <identifier>

Assigment Expression

<assignment> -> <identifier>=<expression> | <declaration> = <expression>

Relational Expression

<relational> -> <expression> < <expression>

| <expression> > <expression>

| <expression> <= <expression>

| <expression> != <expression>

| <expression> == <expression>

| <expression> && <expression>

| <expression> || <expression>

| ! <relational>

Statements

Statement

<statement> -> ; | <expression>;| {<statement>} | L | J | IF | SWITCH | FOR | WHILE | DO | CALL

C - Case Statements

C -> case<identifier>:<statement> | default:<statement> | C

L - Labelled Statements

L -> <identifier>:<statement>

J - Jump Statements

J -> return; | return<expression>; | goto<identifier>; | break; | continue;

Branching Constructs

if construct

IF -> if(<expression>)<statement>else<statement> | if(<expression>)<statement>

switch construct

SWITCH -> switch(<expression>){C}

Loop Constructs

for loop construct

FOR -> for(;;)S | for(<expression>;<relational>;)<statement> | for(<expression>;<relational>;<expression>)<statement>

while loop construct

WHILE -> while(<relational>)<statement>

do while loop construct

DO -> do{<statement>}while(<relational>);

Functions

Function Declaration

FUNCTIONDEC -> <declaration> (P);

P -> <declaration> | <declaration>, <declaration>

Function Definition

FUNCTION -> <declaration> (P)<statement> | <identifier>(P)<statement>

Function Call

CALL -> <identifier>(Z);

Z -> <identifier> | <identifier>, <identifier>

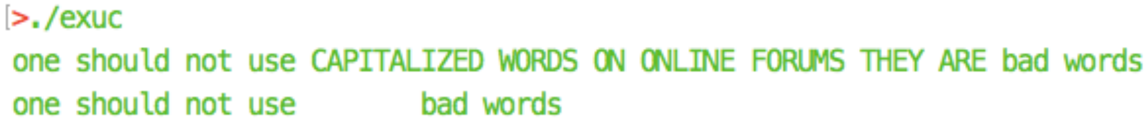
3) Lex Programs

Remove Upper Case Letters

Code

```
%%
[A-Z]+
```

Output



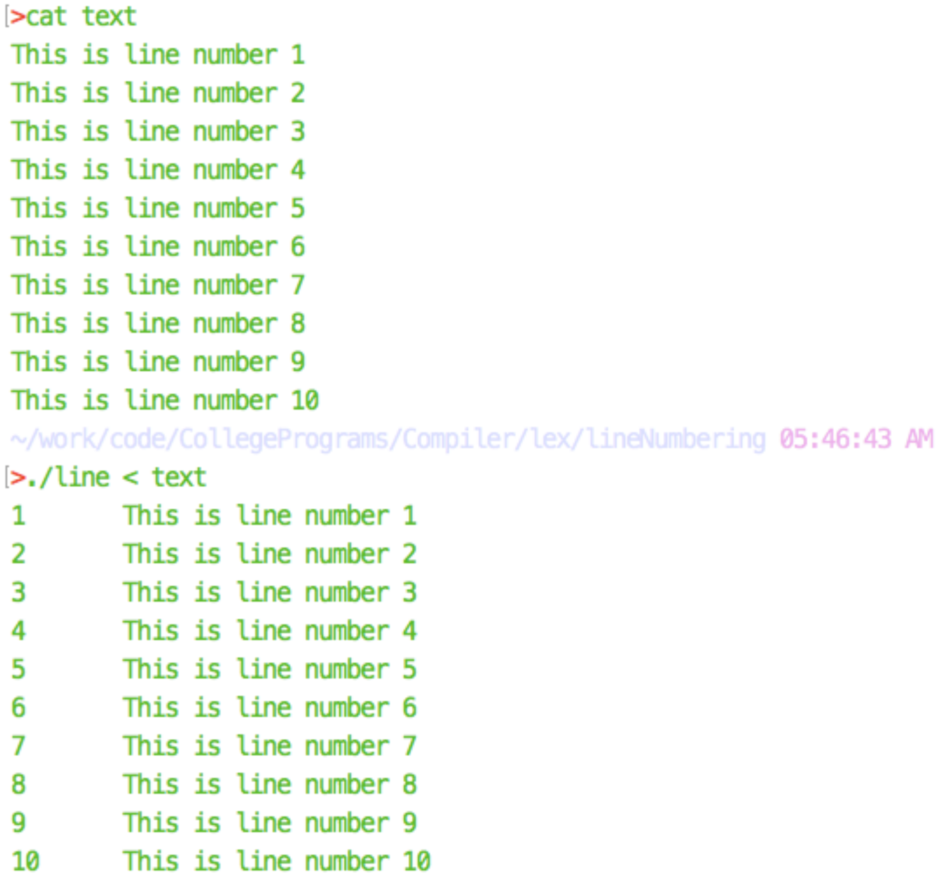
```
[>./exuc
one should not use CAPITALIZED WORDS ON ONLINE FORUMS THEY ARE bad words
one should not use        bad words
```

Line Numbering

Code

```
%%
\n      { yylineno++; printf("\n"); };
^.*$    printf("%d\t%s", yylineno, yytext);
```

Output



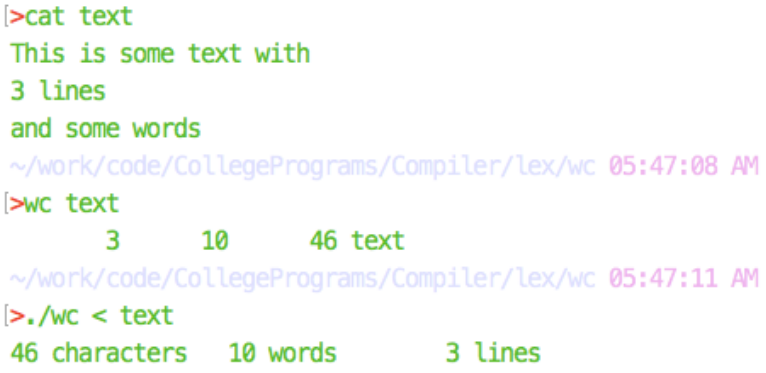
```
[>cat text
This is line number 1
This is line number 2
This is line number 3
This is line number 4
This is line number 5
This is line number 6
This is line number 7
This is line number 8
This is line number 9
This is line number 10
~/work/code/CollegePrograms/Compiler/lex/lineNumbering 05:46:43 AM
[>./line < text
1       This is line number 1
2       This is line number 2
3       This is line number 3
4       This is line number 4
5       This is line number 5
6       This is line number 6
7       This is line number 7
8       This is line number 8
9       This is line number 9
10      This is line number 10
```

Word Count

Code

```
%{
int charCount = 0, wordCount = 0, lineCount = 0;
%}

%%
\n                  ++charCount, ++lineCount;
[^ \t\n]+           ++wordCount, charCount += yyleng;
.                   ++charCount;
%%

int main (void) {
  yylex();
  printf("%d characters\t%d words\t%d lines\n", charCount, wordCount,
lineCount);
  return 0;
}
```

Output



```
[>cat text
This is some text with
3 lines
and some words
~/work/code/CollegePrograms/Compiler/lex/wc 05:47:08 AM
[>wc text
       3      10      46 text
~/work/code/CollegePrograms/Compiler/lex/wc 05:47:11 AM
[>./wc < text
46 characters   10 words        3 lines
```

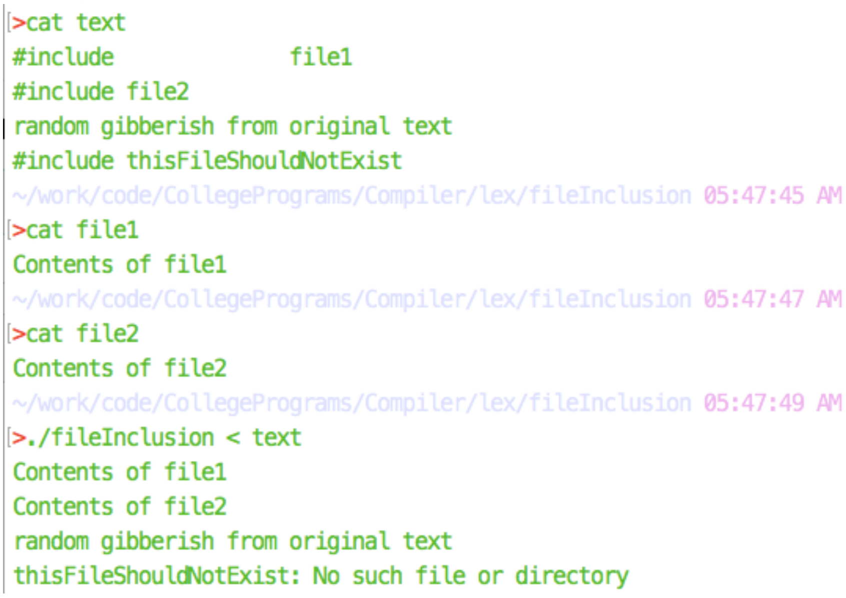
File Inclusion

Code

```
%{
#include <ctype.h>
#include <stdio.h>
static void include (char* s);
static char* trim (char* s);
%}

%%
^"#include".*\n { yytext[yyleng - 1] = '\0'; include(yytext + 8);}
%%
```

```
static char* trim (char* s) {
  while (*s && isspace(*s)) s++;
  return s;
}
static void include (char* s) {
  FILE* fp;
  int i;
  char* fileName = trim(s);

  if ((fp = fopen(fileName, "r"))) {
    while ((i = getc(fp)) != EOF) printf("%c", i);
    fclose(fp);
  } else {
    perror(fileName);
  }

  return;
}
```

Output



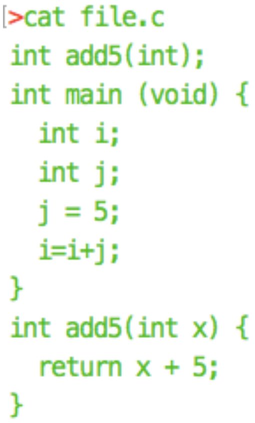
```
[>cat text
#include                 file1
#include file2
random gibberish from original text
#include thisFileShouldNotExist
~/work/code/CollegePrograms/Compiler/lex/fileInclusion 05:47:45 AM
[>cat file1
Contents of file1
~/work/code/CollegePrograms/Compiler/lex/fileInclusion 05:47:47 AM
[>cat file2
Contents of file2
~/work/code/CollegePrograms/Compiler/lex/fileInclusion 05:47:49 AM
[>./fileInclusion < text
Contents of file1
Contents of file2
random gibberish from original text
thisFileShouldNotExist: No such file or directory
```

Lexical Analyzer for C

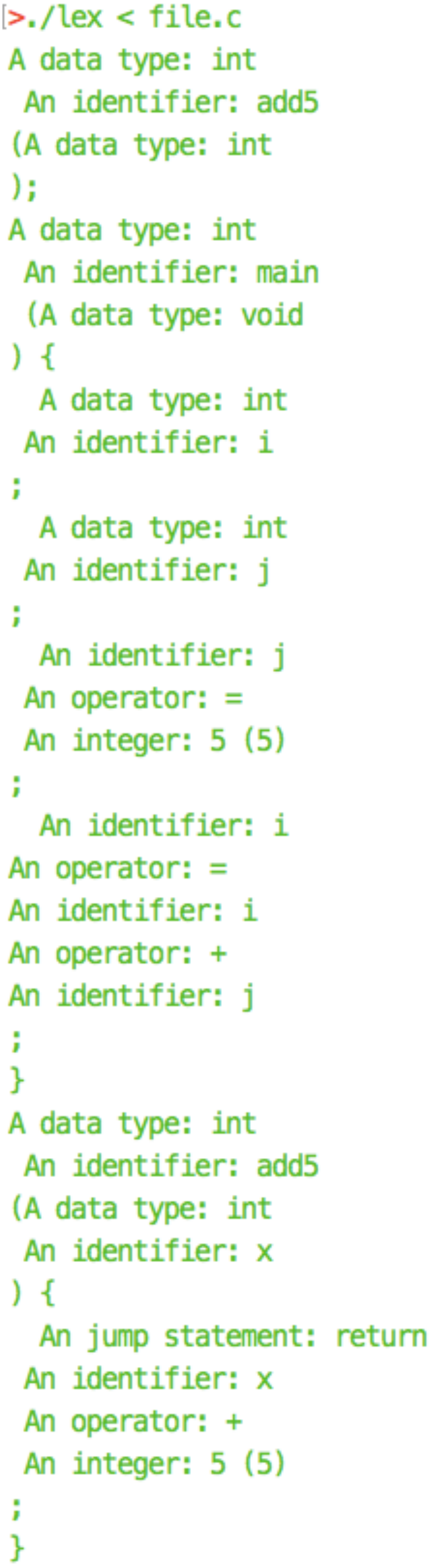
Code

```
%{
/* need this for the call to atof() below */
#include <math.h>
%}

WHITESPACE                [ \t]*
TYPE                      "int"|"char"|"float"|"double"|"void"
OPERATOR                  "+"|"-"|"<"|">"|"*"|"/"|"="
DIGIT                     [0-9]
LETTER                    [a-zA-Z]
NUMBER                    {DIGIT}+(\.{DIGIT}+)?(e[+\-]?{DIGIT}+)?
IDENTIFIER                [a-zA-Z_$][a-zA-Z_$0-9]*
JUMP                      break|return|continue|goto

%%
{TYPE}                    printf("A data type: %s\n", yytext);
{DIGIT}+                  printf("An integer: %s (%d)\n", yytext, atoi(yytext));
{DIGIT}+"."{DIGIT}*       printf("A floating constant: %s (%g)\n", yytext,
atof(yytext));

{JUMP}                    printf("An jump statement: %s\n",yytext );
{IDENTIFIER}              printf("An identifier: %s\n", yytext);
{OPERATOR}                printf("An operator: %s\n",yytext );
%%

int main(void) {
  yyin = stdin;
  yylex();
  return 0;
}
```

Output



```
>cat file.c
int add5(int);
int main (void) {
  int i;
  int j;
  j = 5;
  i=i+j;
}
int add5(int x) {
  return x + 5;
}
```



```
[>./lex < file.c
A data type: int
 An identifier: add5
(A data type: int
);
A data type: int
 An identifier: main
 (A data type: void
) {
  A data type: int
 An identifier: i
;
  A data type: int
 An identifier: j
;
  An identifier: j
 An operator: =
 An integer: 5 (5)
;
  An identifier: i
An operator: =
An identifier: i
An operator: +
An identifier: j
;
}
A data type: int
 An identifier: add5
(A data type: int
 An identifier: x
) {
  An jump statement: return
 An identifier: x
 An operator: +
 An integer: 5 (5)
;
}
```

4) Calculator in yacc

calc.y

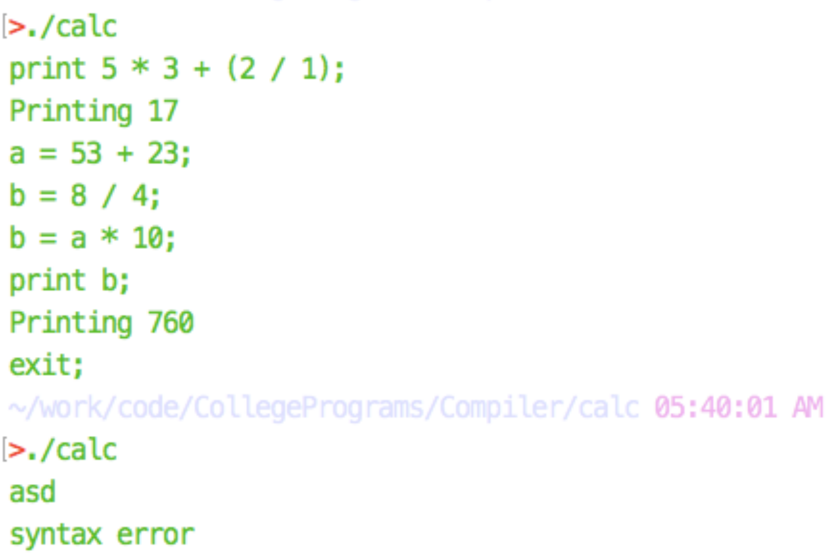
```
%{
 #include <stdio.h>
 #include <stdlib.h>
 #include <math.h>
 void yyerror (char *s);
 int symbols[52];
 int getSymbolValue (char symbol);
 void setSymbolValue (char symbol, int val);
%}

%union {int num; char id;}
%start line
// Some #defines
%token print
%token exit_command
// Some #defines with their types
%token <num> number
%token <id>  identifier
%type  <num> line exp exp1 exp2 term
%type  <id>  assignment

%%

/* descriptions of expected inputs    corresponding actions (in C) */

line: assignment ';'              { ; }
   | exit_command ';'             { exit(EXIT_SUCCESS); }
   | print exp ';'               { printf("Printing %d\n", $2); }
   | line assignment ';'           { ; }
   | line print exp ';'           { printf("Printing %d\n", $3); }
   | line exit_command ';'         { exit(EXIT_SUCCESS); }
   ;

assignment : identifier '=' exp      { setSymbolValue($1,$3); }
        ;

exp    : term                  { $$ = $1; }
      | exp '+' exp1            { $$ = $1 + $3; }
      | exp '-' exp1           { $$ = $1 - $3; }
      | exp1                 { $$ = $1; }
      ;
```

```
exp1    : term                     { $$ = $1; }
      | exp1 '*' exp2             { $$ = $1 * $3; }
      | exp1 '/' exp2             { $$ = $1 / $3; }
      | exp2                    { $$ = $1; }
      ;

exp2    : term                     { $$ = $1; }
      | '(' exp ')'              { $$ = $2; }
      ;

term    : number                    { $$ = $1; }
      | identifier                { $$ = getSymbolValue($1); }
      ;

%%

int computeSymbolIndex (char token) {
  int idx = -1;
  if(islower(token)) {
    idx = token - 'a' + 26;
  } else if(isupper(token)) {
    idx = token - 'A';
  }
  return idx;
}

int getSymbolValue(char symbol) {
  return symbols[computeSymbolIndex(symbol)];
}

void setSymbolValue(char symbol, int val) {
  symbols[computeSymbolIndex(symbol)] = val;
}

int main (void) {
  int i;
  // Initialize symbol table
  for(i=0; i < 52; i++) {
    symbols[i] = 0;
  }
  return yyparse ( );
}

void yyerror (char *s) {
  fprintf (stderr, "%s\n", s);
}
```

calc.l

```
%{
#include "y.tab.h"
extern char* yytext;
extern void yyerror (char *s);
%}

%%
"print"          { return print; }
"exit"           { return exit_command; }
[a-zA-Z]         { yylval.id = yytext[0]; return identifier; }
[0-9]+           { yylval.num = atoi(yytext); return number; }
[ \t\n]          { ; }
[-+/*()=;]       { return yytext[0]; }
.                { printf("%s", yytext); yyerror ("Unexpected character"); }
%%

int yywrap (void) { return 1; }
```

Output



```
[>./calc
 print 5 * 3 + (2 / 1);
 Printing 17
 a = 53 + 23;
 b = 8 / 4;
 b = a * 10;
 print b;
 Printing 760
 exit;
 ~/work/code/CollegePrograms/Compiler/calc 05:40:01 AM
[>./calc
 asd
 syntax error
```