Report on

Mini-compiler for the "if-else" and "for" constructs of Python

Submitted in partial fulfillment of the requirements for ***Sem VI***

Compiler Design

Bachelor of Technology
in
Computer Science & Engineering

Submitted by:

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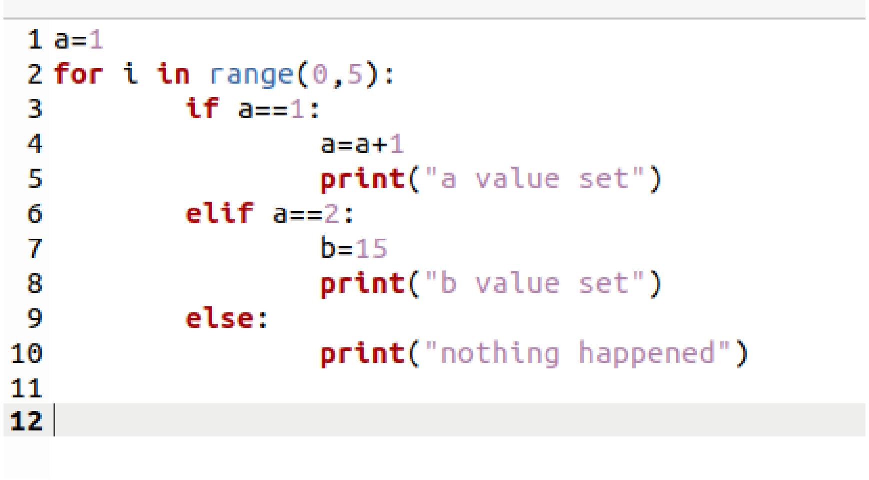
TABLE OF CONTENTS

INTRODUCTION

This is the report for our compiler design project, a mini-compiler designed for the “if-else” and “for” constructs of Python, using the Lex and Yacc tools. Provided with an input file, the compiler generates tokens and builds a symbol table, based on the context free grammar in the Yacc file. An abstract syntax tree is also constructed by the parser, which is then used to create the three address code and quadruples in the intermediate representation phase. The intermediate representation is then optimised using several optimisation techniques.

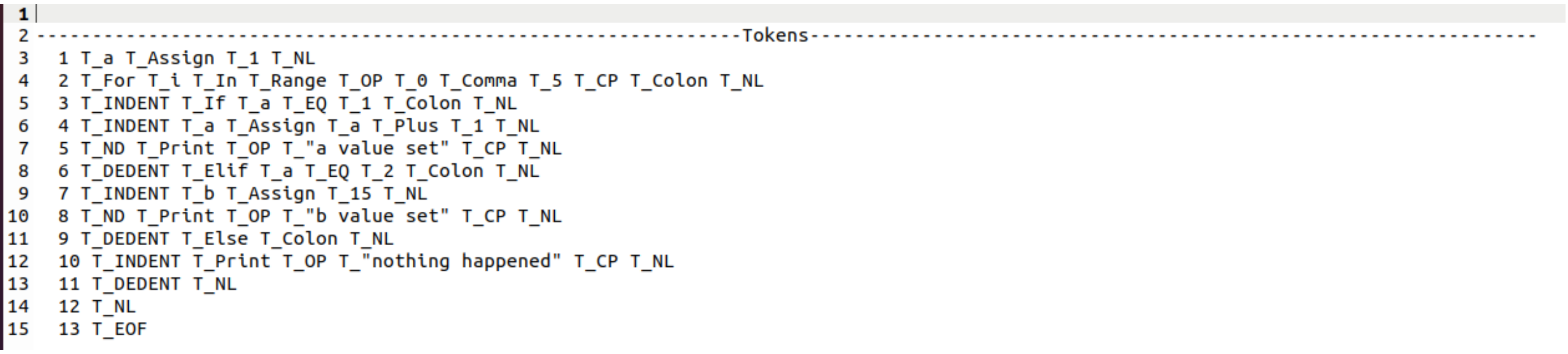
Sample Input



```
a=1
for i in range(0,5):
        if a==1:
                a=a+1
                print("a value set")
        elif a==2:
                b=15
                print("b value set")
        else:
                print("nothing happened")

```

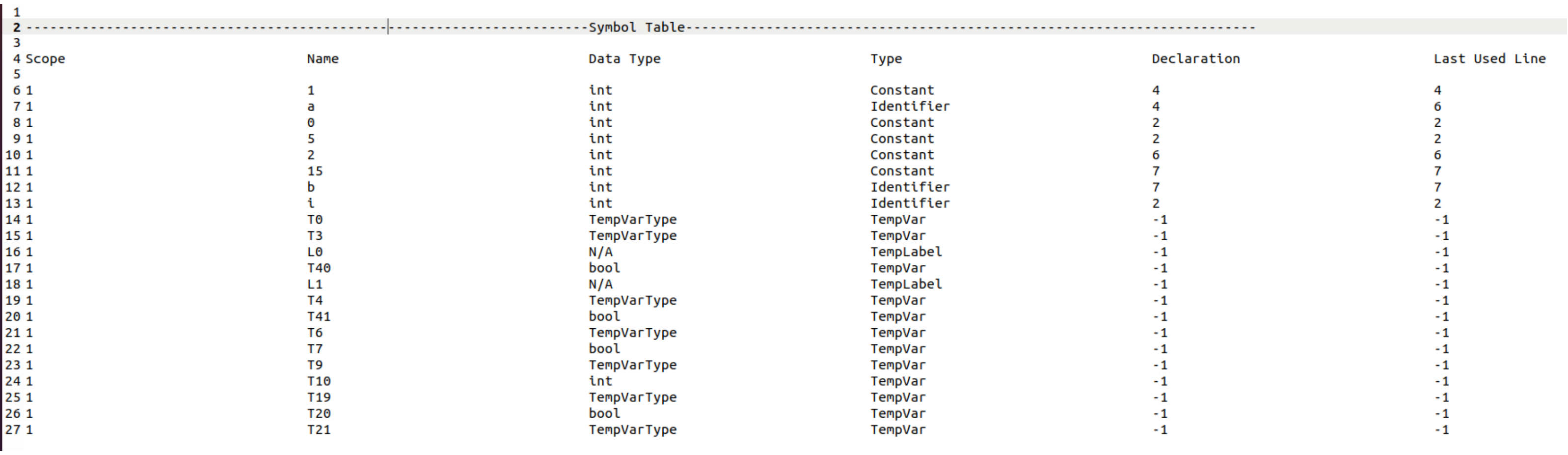
Sample Output

Tokens-



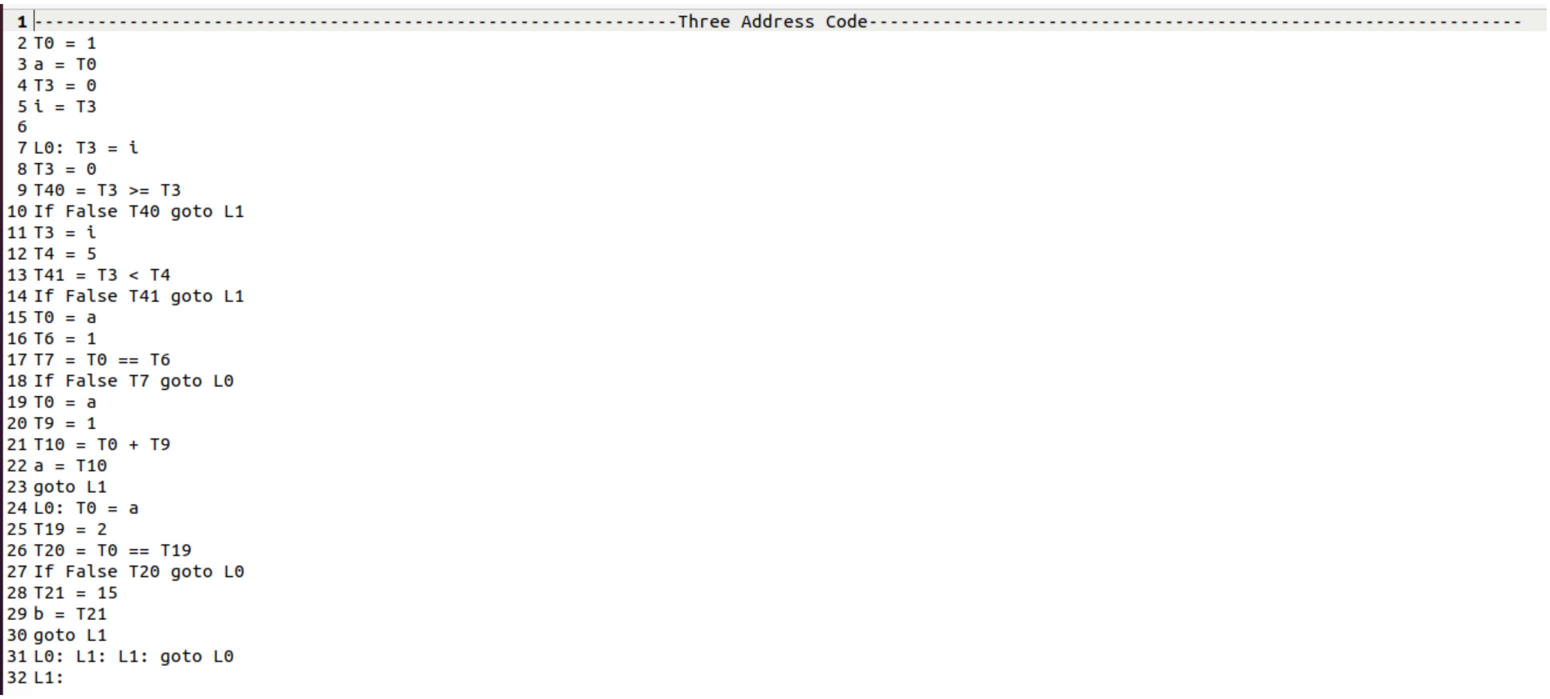
```

--------------------------------------------------------------Tokens----------------------------------------------------------------
 1 T_a T_Assign T_1 T_NL
 2 T_For T_i T_In T_Range T_OP T_0 T_Comma T_5 T_CP T_Colon T_NL
 3 T_INDENT T_If T_a T_EQ T_1 T_Colon T_NL
 4 T_INDENT T_a T_Assign T_a T_Plus T_1 T_NL
 5 T_ND T_Print T_OP T_"a value set" T_CP T_NL
 6 T_DEDENT T_Elif T_a T_EQ T_2 T_Colon T_NL
 7 T_INDENT T_b T_Assign T_15 T_NL
 8 T_ND T_Print T_OP T_"b value set" T_CP T_NL
 9 T_DEDENT T_Else T_Colon T_NL
 10 T_INDENT T_Print T_OP T_"nothing happened" T_CP T_NL
 11 T_DEDENT T_NL
 12 T_NL
 13 T_EOF
```

Symbol Table-



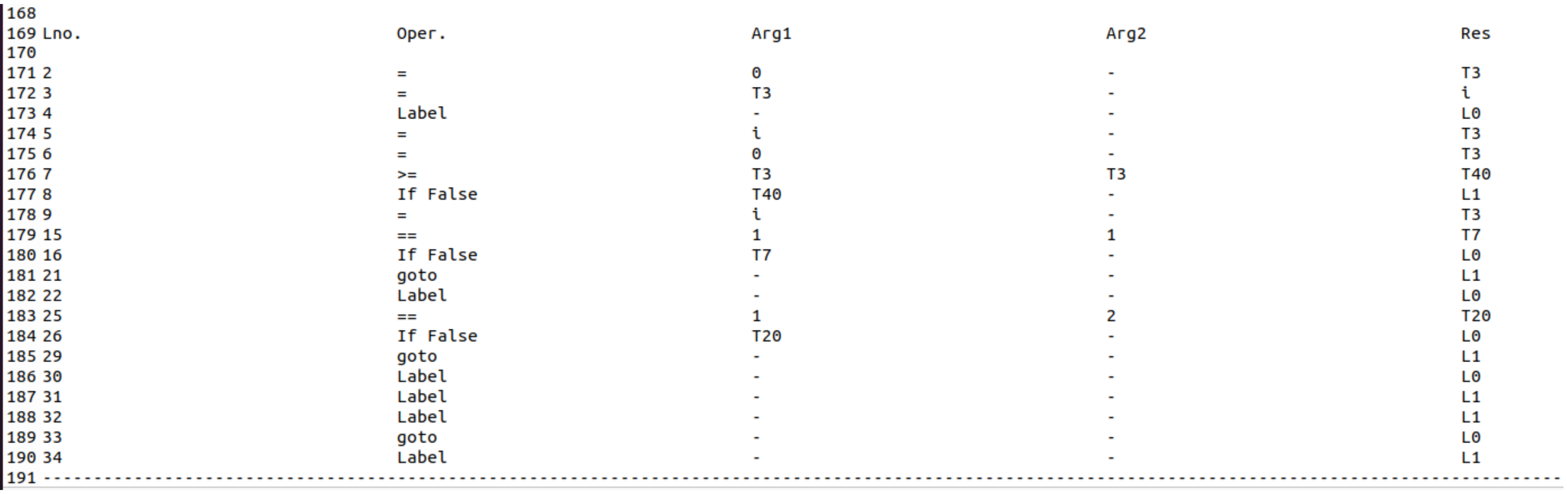
```
------------------------------------------------------------------Symbol Table--------------------------------------------------------------------------

Scope                                     Name                                      Data Type                                 Type                                      Declaration                               Last Used Line

1                                         1                                         int                                       Constant                                  4                                         4
1                                         a                                         int                                       Identifier                                4                                         6
1                                         0                                         int                                       Constant                                  2                                         2
1                                         5                                         int                                       Constant                                  2                                         2
1                                         2                                         int                                       Constant                                  6                                         6
1                                         15                                        int                                       Constant                                  7                                         7
1                                         b                                         int                                       Identifier                                7                                         7
1                                         i                                         int                                       Identifier                                2                                         2
1                                         T0                                        TempVarType                               TempVar                                   -1                                        -1
1                                         T3                                        TempVarType                               TempVar                                   -1                                        -1
1                                         L0                                        N/A                                       TempLabel                                 -1                                        -1
1                                         T40                                       bool                                      TempVar                                   -1                                        -1
1                                         L1                                        N/A                                       TempLabel                                 -1                                        -1
1                                         T4                                        TempVarType                               TempVar                                   -1                                        -1
1                                         T41                                       bool                                      TempVar                                   -1                                        -1
1                                         T6                                        TempVarType                               TempVar                                   -1                                        -1
1                                         T7                                        bool                                      TempVar                                   -1                                        -1
1                                         T9                                        TempVarType                               TempVar                                   -1                                        -1
1                                         T10                                       int                                       TempVar                                   -1                                        -1
1                                         T19                                       TempVarType                               TempVar                                   -1                                        -1
1                                         T20                                       bool                                      TempVar                                   -1                                        -1
1                                         T21                                       TempVarType                               TempVar                                   -1                                        -1
```

TAC-



```
-------------------------------------------------------------Three Address Code--------------------------------------------------------------
T0 = 1
a = T0
T3 = 0
i = T3

L0: T3 = i
T3 = 0
T40 = T3 >= T3
If False T40 goto L1
T3 = i
T4 = 5
T41 = T3 < T4
If False T41 goto L1
T0 = a
T6 = 1
T7 = T0 == T6
If False T7 goto L0
T0 = a
T9 = 1
T10 = T0 + T9
a = T10
goto L1
L0: T0 = a
T19 = 2
T20 = T0 == T19
If False T20 goto L0
T21 = 15
b = T21
goto L1
L0: L1: L1: goto L0
L1:
```

Quads (after all the optimisations)-



```

Lno.                    Oper.                   Arg1                    Arg2                    Res

2                       =                       0                       -                       T3
3                       =                       T3                      -                       i
4                       Label                   -                       -                       L0
5                       =                       i                       -                       T3
6                       =                       0                       -                       T3
7                       >=                      T3                      T3                      T40
8                       If False                T40                     -                       L1
9                       =                       i                       -                       T3
15                      ==                      1                       1                       T7
16                      If False                T7                      -                       L0
21                      goto                    -                       -                       L1
22                      Label                   -                       -                       L0
25                      ==                      1                       2                       T20
26                      If False                T20                     -                       L0
29                      goto                    -                       -                       L1
30                      Label                   -                       -                       L0
31                      Label                   -                       -                       L1
32                      Label                   -                       -                       L1
33                      goto                    -                       -                       L0
34                      Label                   -                       -                       L1
-----------------------------------------------------------------------------------------------------------------------
```

ARCHITECTURE OF LANGUAGE

Python is a vast language. Some of the features we have implemented-

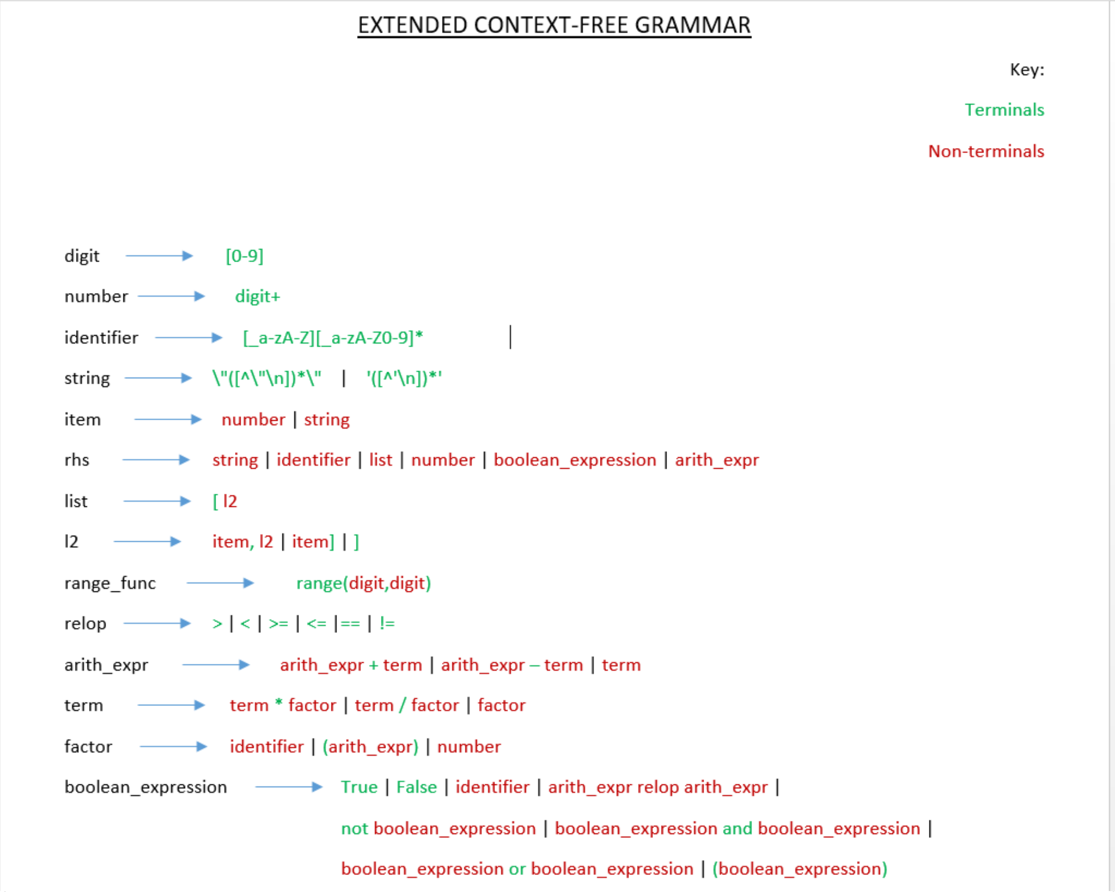
- “if-else” and “for” constructs (allows nesting)
- function definitions (allows nesting) and function calls
- import statements
- string, integer, boolean, list data types
- single and multiline comments
- print, break, pass, void return statements
- arithmetic, relational, logical, membership operations
- scoping

LITERATURE SURVEY

For the most part, we’ve used lex and yacc learning material provided to us by our professors, along with documentation found online, and from sites such as GeeksforGeeks and Stack Overflow.

A Guide to Lex & Yacc (ncsu.edu)

CONTEXT FREE GRAMMAR



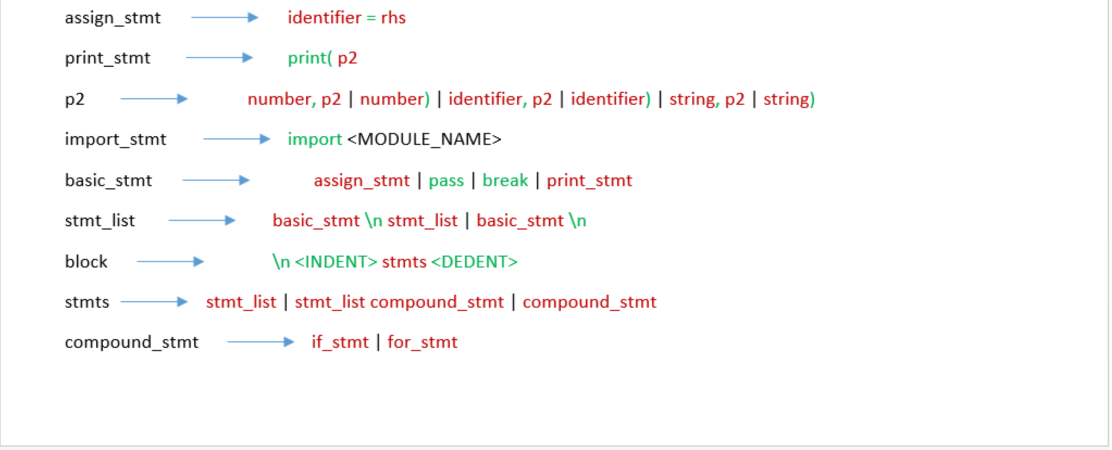
EXTENDED CONTEXT-FREE GRAMMAR

Key:

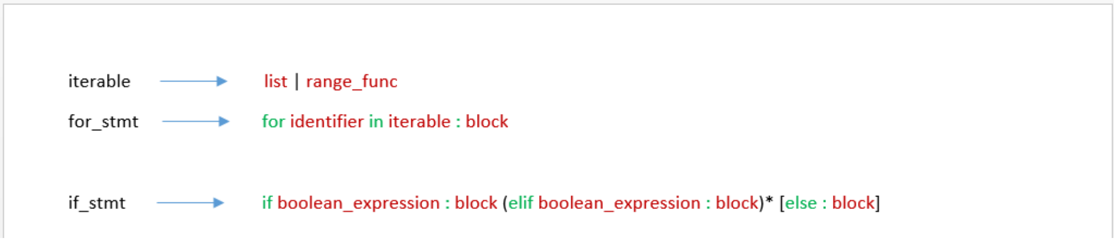
Terminals

Non-terminals

```
digit              →   [0-9]
number             →   digit+
identifier         →   [_a-zA-Z][_a-zA-Z0-9]*          |
string             →   \"([^\"\n])*\"   |   '([^'\n])*'
item               →   number | string
rhs                →   string | identifier | list | number | boolean_expression | arith_expr
list               →   [ l2
l2                 →   item, l2 | item] | ]
range_func         →   range(digit,digit)
relop              →   > | < | >= | <= |== | !=
arith_expr         →   arith_expr + term | arith_expr – term | term
term               →   term * factor | term / factor | factor
factor             →   identifier | (arith_expr) | number
boolean_expression →   True | False | identifier | arith_expr relop arith_expr |
                       not boolean_expression | boolean_expression and boolean_expression |
                       boolean_expression or boolean_expression | (boolean_expression)
```



```
assign_stmt        →   identifier = rhs
print_stmt         →   print( p2
p2                 →   number, p2 | number) | identifier, p2 | identifier) | string, p2 | string)
import_stmt        →   import <MODULE_NAME>
basic_stmt         →   assign_stmt | pass | break | print_stmt
stmt_list          →   basic_stmt \n stmt_list | basic_stmt \n
block              →   \n <INDENT> stmts <DEDENT>
stmts              →   stmt_list | stmt_list compound_stmt | compound_stmt
compound_stmt      →   if_stmt | for_stmt
```



```
iterable           →   list | range_func
for_stmt           →   for identifier in iterable : block


if_stmt            →   if boolean_expression : block (elif boolean_expression : block)* [else : block]
```

CFG used in yacc-

```
StartDebugger : StartParse T_EndOfFile ;

StartParse : T_NL StartParse | finalStatements T_NL StartParse | finalStatements | ;


constant : T_Number
        | T_String ;

term : T_ID
     | constant
     | list_index ;


list_index : T_ID T_OSB T_Number T_CSB ;


basic_stmt : pass_stmt
           | break_stmt
           | import_stmt
           | assign_stmt
           | arith_exp
           | bool_exp
           | print_stmt
           | return_stmt;

pass_stmt : T_Pass ;

break_stmt : T_Break ;

import_stmt : T_Import T_ID ;

assign_stmt : T_ID T_Assign arith_exp
            | T_ID T_Assign bool_exp
            | T_ID  T_Assign func_call
            | T_ID T_Assign T_OSB call_args T_CSB ;

arith_exp : term
          | arith_exp  T_Plus  arith_exp
          | arith_exp  T_Minus  arith_exp
          | arith_exp  T_Mult  arith_exp
          | arith_exp  T_Div  arith_exp
          | T_Minus arith_exp
          | T_OP arith_exp T_CP ;


bool_exp : bool_term T_Or bool_term
         | bool_term T_And bool_term
         | arith_exp T_EQ arith_exp
         | arith_exp T_GT arith_exp
         | arith_exp T_LT arith_exp
         | arith_exp T_GE arith_exp
         | arith_exp T_LE arith_exp
```

```
          | arith_exp T_NE arith_exp
          | arith_exp T_In T_ID
          | bool_term ;

bool_term : bool_factor
           | T_True
           | T_False ;

bool_factor : T_Not bool_factor
             | T_OP bool_exp T_CP;


print_stmt : T_Print T_OP call_args T_CP ;


return_stmt : T_Return ;



finalStatements : basic_stmt
                 | cmpd_stmt
                 | func_def
                 | func_call
                 | error T_NL ;

cmpd_stmt : if_stmt
           | for_stmt ;

if_stmt : T_If bool_exp T_Colon start_block
         | T_If bool_exp T_Colon start_block elif_stmts ;

elif_stmts : else_stmt
            | T_Elif bool_exp T_Colon start_block elif_stmts ;

else_stmt : T_Else T_Colon start_block ;


iterable: T_ID
              | T_Range T_OP T_Number T_Comma T_Number T_CP ;

for_stmt : T_For T_ID T_In iterable T_Colon start_block ;





start_block : basic_stmt
             | T_NL T_INDENT finalStatements block ;

block : T_NL T_ND finalStatements block
       | T_NL end_block ;

end_block : T_DEDENT finalStatements
           | T_DEDENT
           | ;
```

```
args : T_ID args_list
     | ;

args_list : T_Comma T_ID args_list | ;


call_list : T_Comma term call_list | ;

call_args : T_ID call_list
          | T_Number call_list
          | T_String call_list
          | ;

func_def : T_Def T_ID T_OP args T_CP T_Colon start_block ;

func_call : T_ID T_OP call_args T_CP ;
```

DESIGN STRATEGY

SYMBOL TABLE CREATION

The symbol table uses two structures, STable and record, for storage.

Each STable variable corresponds to one scope (one symbol table per scope).

The record variables are individual symbol table entries.

STable has members which hold information related to the number of entries, pointers to these entries, the scope of the table, and the parent table.

The members of record have information about the name of the entry, the data type, the line number of declaration, and the line it was last used.

Scope is implemented for Python functions, using a hashing technique to maintain unique scopes (when indentation level is the same, but scope is different).

The information stored in the symbol table can then be used by subsequent phases.

INTERMEDIATE CODE GENERATION

In the parsing phase, an abstract syntax tree is created. In the CFG, the rules specify when and how to push symbols as nodes into the tree.

The compiler uses this syntax tree while creating the intermediate code in the intermediate representation phase. The three address code is generated, and stored in quadruple form.

CODE OPTIMIZATION

This phase implements four optimisation techniques on the quads created in the previous phase. They are-

- Strength Reduction (replaces expensive operations with cheaper ones)
- Constant Propagation (a constant assigned to a variable is substituted when the variable is encountered during compile time instead of runtime)

- Constant Folding (recognises and evaluates constant expressions at compile time rather than computing them at runtime)
- Dead Code Elimination (removes useless or unreachable code)

IMPLEMENTATION DETAILS

SYMBOL TABLE CREATION

The structures used-

```
//structure of a single record in a symbol table
typedef struct record
{
        char *type;
        char *name;
        char *datatype;
        int lineno_declared;
        int lastUseLine;
} record;



//structure of a symbol table
//there is one ST per scope
typedef struct STable
{
        int no;  //index
        int noOfElements;
        int STscope;
        record *Elements;
        int Parent;       //gives position index of parent ST (in array of STs)

} STable;
```

INTERMEDIATE CODE GENERATION

The structures used-

```
//structure for Abstract Syntax Tree node
typedef struct ASTNode
{
        int nodeNo;
        char *NType;    //if the Node is an operator (specifies the operator. ex- +, -, etc)
        int opCount;   //number of operands (children) of the operator node
        struct ASTNode** NextLevel;
        record *id;    //if the Node is an identifier or a constant, this node needs to point to a record in a ST
} Node;


//structure for Quad
```

```
typedef struct Quad
{
        char *Op;    //operator
        char *A1;    //argument 1
        char *A2;    //argument 2
        char *R;    //result

        //can be used to mark a quad as redundant during dead code elimination
        int I;    //(initially holds index no. of the quad in the array)
} Quad;
```

CODE OPTIMIZATION

- Strength Reduction-
    - It iterates through all the quads. If a quad with two arguments is found, and the operator is multiplication ("*"), it converts the expression into a left shift operation. If the operator is division ("/"), it converts the expression into a right shift operation.
    - This only works when the second argument is a power of two.

- Constant Propagation-
    - It iterates through all the quads. If it finds a quad with only one argument, and the argument is of integer type, and the operator is "=", this means that the expression is of a simple assignment type (ex- a=20). Call this quad1.
    - It captures the index of quad1, and iterates through the quads after it. If it finds that any of these quads have their arguments equal to the result of quad1 (ex- b=a+15), it replaces that argument with the argument of quad1 (ex- b=20+15)

- Constant Folding-
    - It iterates through all the quads. If a quad is found with two arguments and both the arguments are of integer type, it checks the operation of that quad.
    - Based on the operation (ex- "+", "*", "/"), it computes the expression, and the result is stored as one of the arguments of the quad, and the operation of the quad is changed to "=".
    - ex- a=5+3 (quad's arg1=5, arg2=3, operation="+") becomes a=8 (quad's arg1=8, operation="=")

- Dead Code Elimination-
    - It iterates through all the quads. For each quad (quad1), it iterates through the remaining quads (quad2). If the result of quad1 is not encountered as either of the arguments of any quad2, this means that the result of quad1 is not used anywhere else, for any computation. This renders the result of quad1 as dead, and it marks quad1 as such.
    - ex- if we have s=30, and s is not being used anywhere else in the code, we can mark the quad for this assignment as dead, thus rejecting that quad.

ERROR HANDLING

The compiler checks to see if a referenced identifier has been declared in the scope. If not, it throws an error, saying that the identifier is being used before declaration.
It also checks to see if the iterable identifier in the for loop is of list type. If it's not, it says that the identifier is not indexable.
Any other syntax error is handled by displaying the line and column number of the point of error.

BUILDING AND RUNNING THE PROGRAM

- The lex file is called project_lex.l, and the yacc file is called project_yacc.y
- The commands to build the program are in a makefile-

```
a.out : lex.yy.c y.tab.c y.tab.h
	gcc lex.yy.c y.tab.c -g -ll -lm

y.tab.c : project_yacc.y
	yacc -Wno-yacc -dv project_yacc.y

lex.yy.c : project_lex.l
	lex project_lex.l

clean :
	rm -rf lex.yy.c y.tab.c y.tab.h a.out y.output Tokens.txt TAC.txt Quads.txt SymbolTable.txt
```

- Upon execution, the resulting token sequence, symbol table, three address code, and quads get stored in Tokens.txt, SymbolTable.txt, TAC.txt, and Quads.txt respectively.
- The executable file takes as input the testing file with the python code (if it's called sample.py)

- Commands to build and run-

```
make -f makefile.mk
./a.out < sample.py
make -f makefile.mk clean
```

SHORTCOMINGS AND FUTURE SCOPE

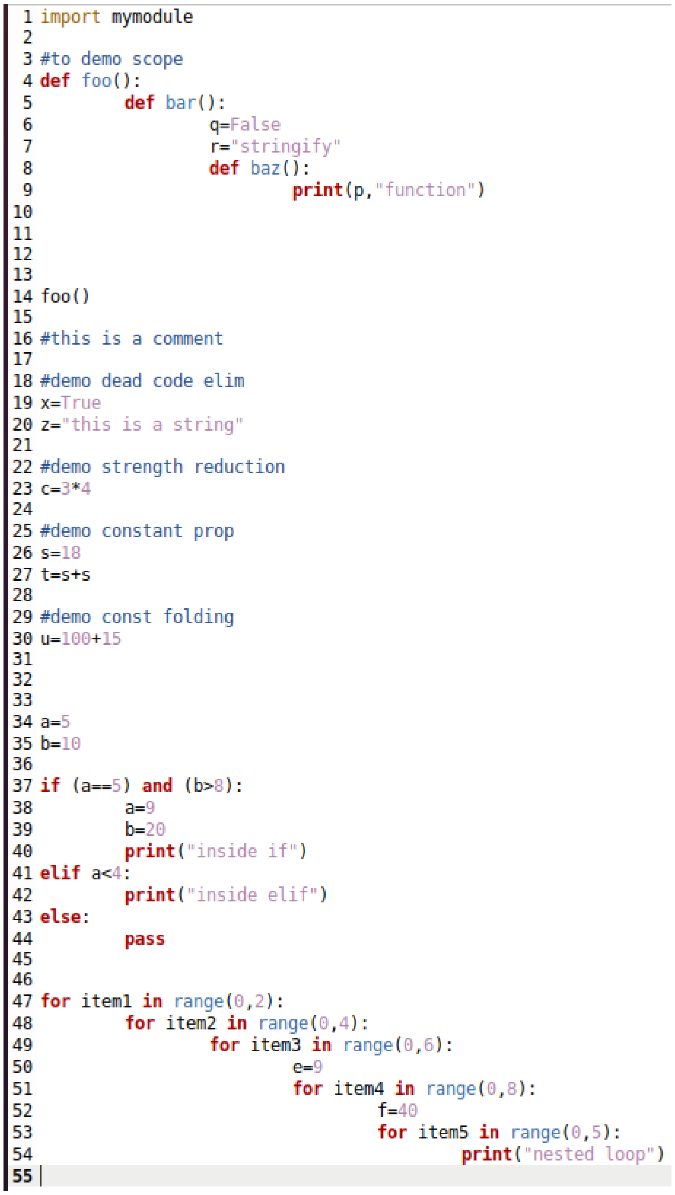
Future scope/Shortcomings-

- Extend range function to take 1 or 3 arguments (currently, it takes exactly 2)
- Extend for loop to include other iterables, for example- strings, tuples (currently, it takes only range and lists)
- Allow for indentation to be done using spaces (currently, it can only be done using tabs)
- Implement operator overloading, so that string operations may be done, too (currently, "+" and "*" only work with integer type arguments)
- Allow for returning values in functions (currently, only void returns can be done)
- Implement loop optimisation techniques

SNAPSHOTS

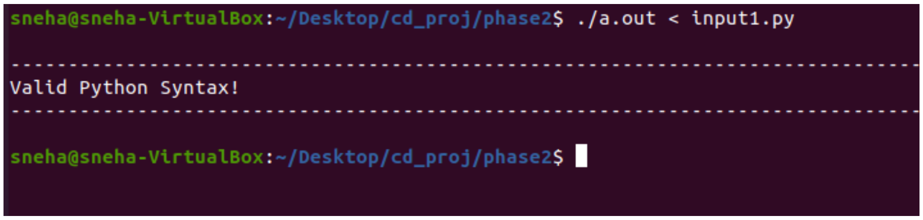
Test file 1-

- Input-



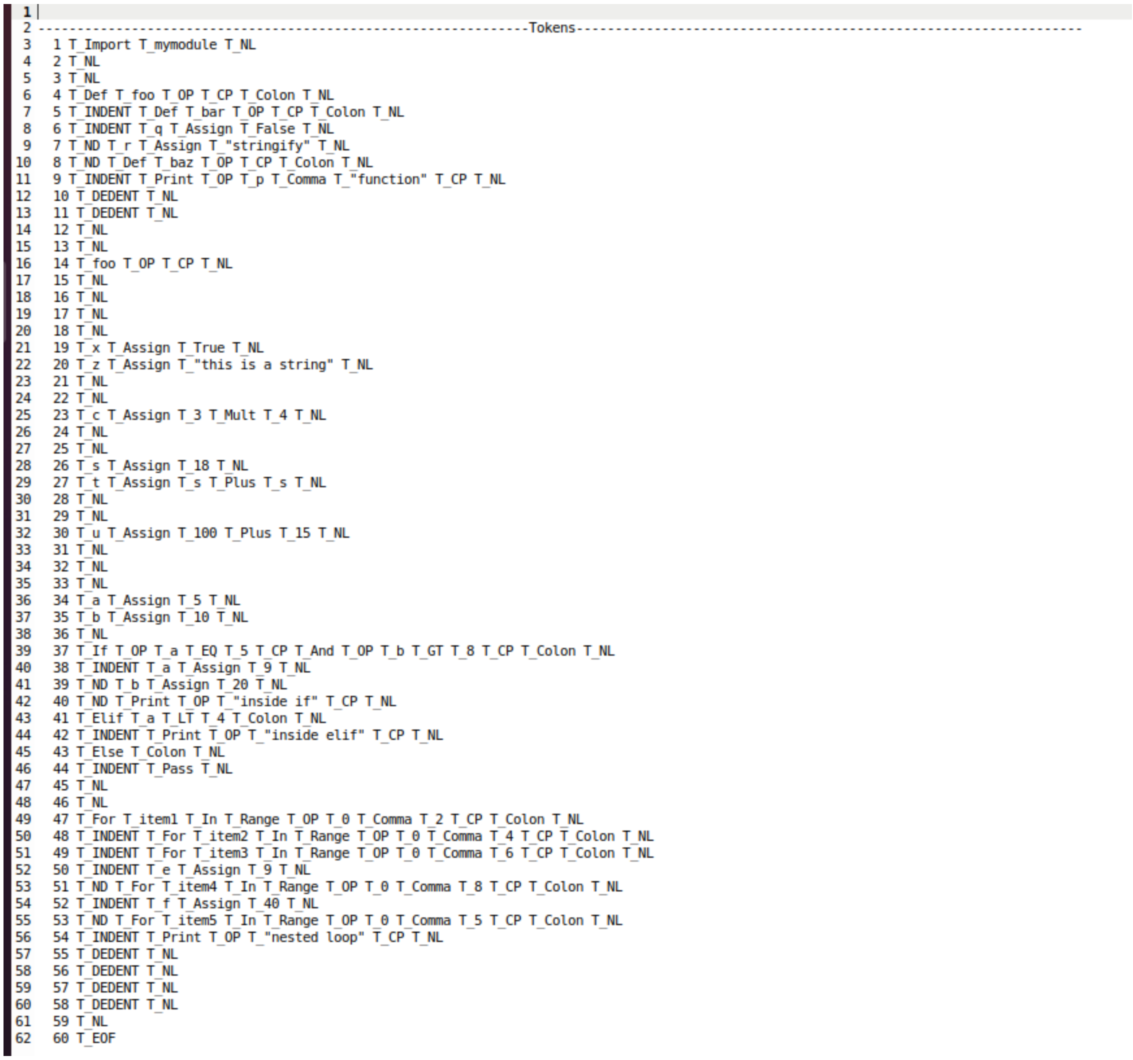
```
import mymodule

#to demo scope
def foo():
        def bar():
                q=False
                r="stringify"
                def baz():
                        print(p,"function")




foo()

#this is a comment

#demo dead code elim
x=True
z="this is a string"

#demo strength reduction
c=3*4

#demo constant prop
s=18
t=s+s

#demo const folding
u=100+15



a=5
b=10

if (a==5) and (b>8):
        a=9
        b=20
        print("inside if")
elif a<4:
        print("inside elif")
else:
        pass


for item1 in range(0,2):
        for item2 in range(0,4):
                for item3 in range(0,6):
                        e=9
                        for item4 in range(0,8):
                                f=40
                                for item5 in range(0,5):
                                        print("nested loop")

```

- Output-



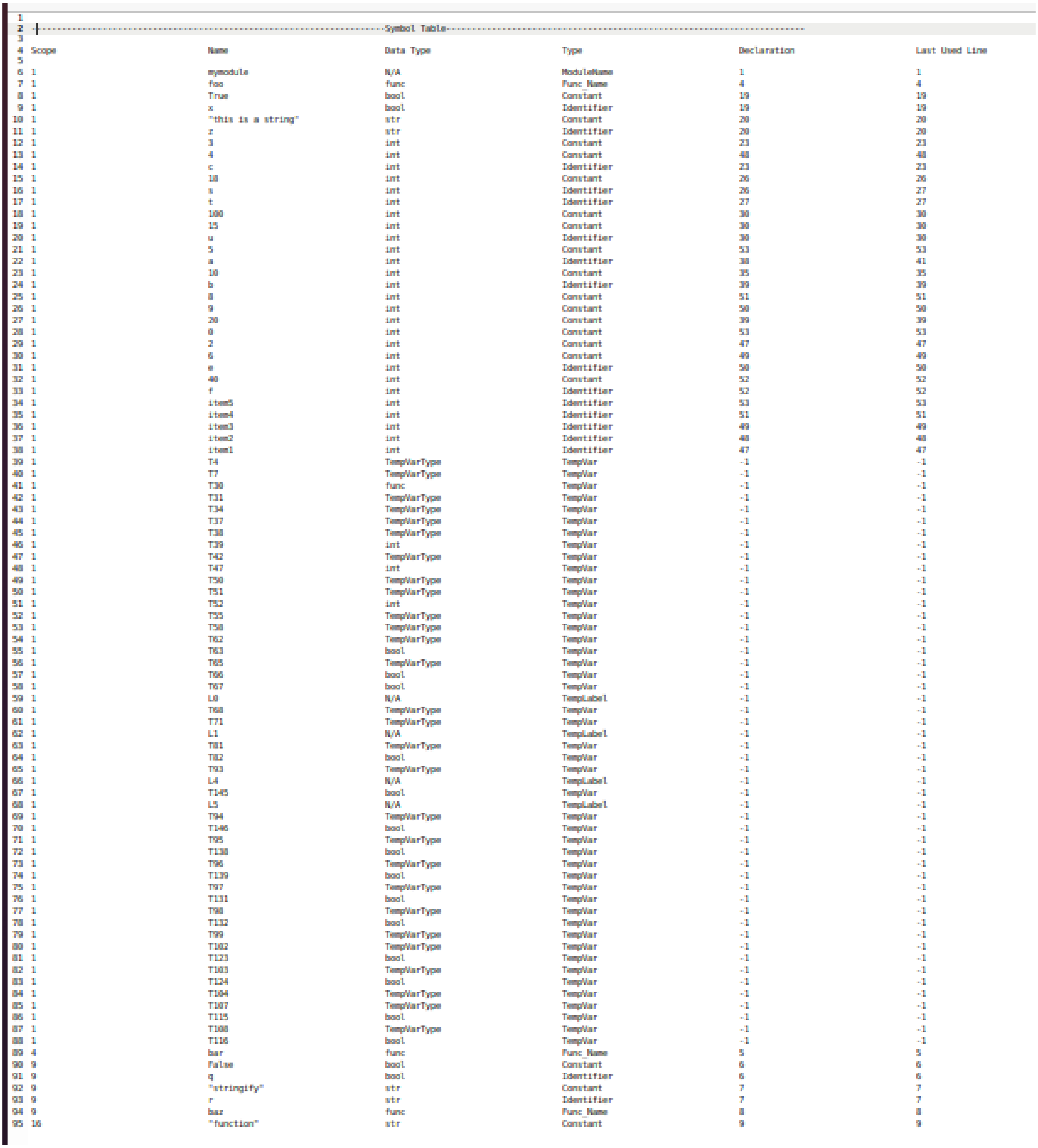
```
sneha@sneha-VirtualBox:~/Desktop/cd_proj/phase2$ ./a.out < input1.py

-------------------------------------------------------------------------------
Valid Python Syntax!
-------------------------------------------------------------------------------

sneha@sneha-VirtualBox:~/Desktop/cd_proj/phase2$ █
```

Tokens-



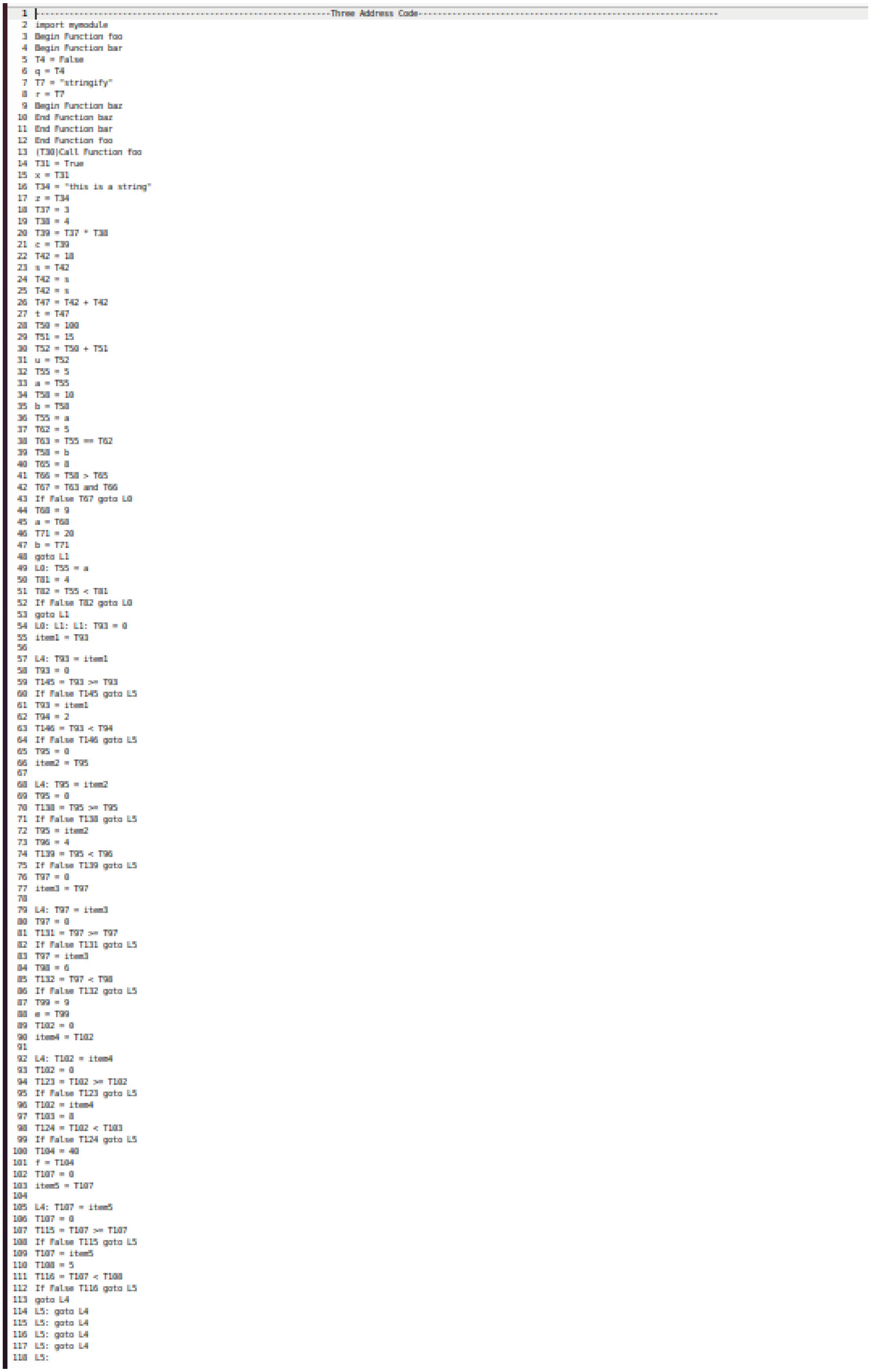
```
---------------------------------------------------------------Tokens-----------------------------------------------------------------
 1 T_Import T_mymodule T_NL
 2 T_NL
 3 T_NL
 4 T_Def T_foo T_OP T_CP T_Colon T_NL
 5 T_INDENT T_Def T_bar T_OP T_CP T_Colon T_NL
 6 T_INDENT T_q T_Assign T_False T_NL
 7 T_ND T_r T_Assign T_"stringify" T_NL
 8 T_ND T_Def T_baz T_OP T_CP T_Colon T_NL
 9 T_INDENT T_Print T_OP T_p T_Comma T_"function" T_CP T_NL
 10 T_DEDENT T_NL
 11 T_DEDENT T_NL
 12 T_NL
 13 T_NL
 14 T_foo T_OP T_CP T_NL
 15 T_NL
 16 T_NL
 17 T_NL
 18 T_NL
 19 T_x T_Assign T_True T_NL
 20 T_z T_Assign T_"this is a string" T_NL
 21 T_NL
 22 T_NL
 23 T_c T_Assign T_3 T_Mult T_4 T_NL
 24 T_NL
 25 T_NL
 26 T_s T_Assign T_18 T_NL
 27 T_t T_Assign T_s T_Plus T_s T_NL
 28 T_NL
 29 T_NL
 30 T_u T_Assign T_100 T_Plus T_15 T_NL
 31 T_NL
 32 T_NL
 33 T_NL
 34 T_a T_Assign T_5 T_NL
 35 T_b T_Assign T_10 T_NL
 36 T_NL
 37 T_If T_OP T_a T_EQ T_5 T_CP T_And T_OP T_b T_GT T_8 T_CP T_Colon T_NL
 38 T_INDENT T_a T_Assign T_9 T_NL
 39 T_ND T_b T_Assign T_20 T_NL
 40 T_ND T_Print T_OP T_"inside if" T_CP T_NL
 41 T_Elif T_a T_LT T_4 T_Colon T_NL
 42 T_INDENT T_Print T_OP T_"inside elif" T_CP T_NL
 43 T_Else T_Colon T_NL
 44 T_INDENT T_Pass T_NL
 45 T_NL
 46 T_NL
 47 T_For T_item1 T_In T_Range T_OP T_0 T_Comma T_2 T_CP T_Colon T_NL
 48 T_INDENT T_For T_item2 T_In T_Range T_OP T_0 T_Comma T_4 T_CP T_Colon T_NL
 49 T_INDENT T_For T_item3 T_In T_Range T_OP T_0 T_Comma T_6 T_CP T_Colon T_NL
 50 T_INDENT T_e T_Assign T_9 T_NL
 51 T_ND T_For T_item4 T_In T_Range T_OP T_0 T_Comma T_8 T_CP T_Colon T_NL
 52 T_INDENT T_f T_Assign T_40 T_NL
 53 T_ND T_For T_item5 T_In T_Range T_OP T_0 T_Comma T_5 T_CP T_Colon T_NL
 54 T_INDENT T_Print T_OP T_"nested loop" T_CP T_NL
 55 T_DEDENT T_NL
 56 T_DEDENT T_NL
 57 T_DEDENT T_NL
 58 T_DEDENT T_NL
 59 T_NL
 60 T_EOF
```

Symbol Table-



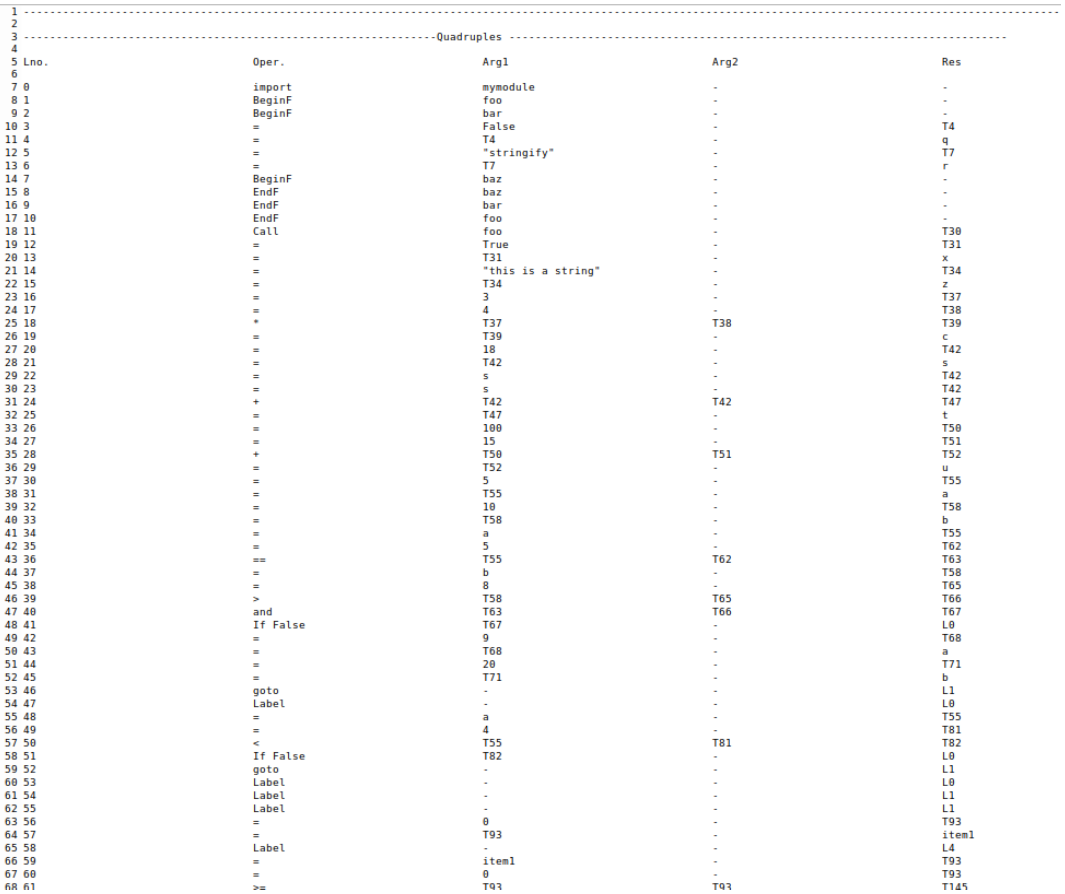
```

-------------------------------------------------------------------Symbol Table------------------------------------------------------------------------

Scope                               Name                                Data Type                           Type                                Declaration                         Last Used Line

1                                   mymodule                            N/A                                 ModuleName                          1                                   1
1                                   foo                                 func                                Func_Name                           4                                   4
1                                   True                                bool                                Constant                            19                                  19
1                                   x                                   bool                                Identifier                          19                                  19
1                                   "this is a string"                  str                                 Constant                            20                                  20
1                                   r                                   str                                 Identifier                          20                                  20
1                                   3                                   int                                 Constant                            23                                  23
1                                   4                                   int                                 Constant                            48                                  48
1                                   c                                   int                                 Identifier                          23                                  23
1                                   18                                  int                                 Constant                            26                                  26
1                                   s                                   int                                 Identifier                          26                                  27
1                                   t                                   int                                 Identifier                          27                                  27
1                                   100                                 int                                 Constant                            30                                  30
1                                   15                                  int                                 Constant                            30                                  30
1                                   u                                   int                                 Identifier                          30                                  30
1                                   5                                   int                                 Constant                            53                                  53
1                                   a                                   int                                 Identifier                          38                                  41
1                                   10                                  int                                 Constant                            35                                  35
1                                   b                                   int                                 Identifier                          39                                  39
1                                   8                                   int                                 Constant                            51                                  51
1                                   9                                   int                                 Constant                            50                                  50
1                                   20                                  int                                 Constant                            39                                  39
1                                   0                                   int                                 Constant                            53                                  53
1                                   2                                   int                                 Constant                            47                                  47
1                                   6                                   int                                 Constant                            49                                  49
1                                   e                                   int                                 Identifier                          50                                  50
1                                   40                                  int                                 Constant                            52                                  52
1                                   f                                   int                                 Identifier                          52                                  52
1                                   item5                               int                                 Identifier                          53                                  53
1                                   item4                               int                                 Identifier                          51                                  51
1                                   item3                               int                                 Identifier                          49                                  49
1                                   item2                               int                                 Identifier                          48                                  48
1                                   item1                               int                                 Identifier                          47                                  47
1                                   T4                                  TempVarType                         TempVar                             -1                                  -1
1                                   T7                                  TempVarType                         TempVar                             -1                                  -1
1                                   T30                                 func                                TempVar                             -1                                  -1
1                                   T31                                 TempVarType                         TempVar                             -1                                  -1
1                                   T34                                 TempVarType                         TempVar                             -1                                  -1
1                                   T37                                 TempVarType                         TempVar                             -1                                  -1
1                                   T38                                 TempVarType                         TempVar                             -1                                  -1
1                                   T39                                 int                                 TempVar                             -1                                  -1
1                                   T42                                 TempVarType                         TempVar                             -1                                  -1
1                                   T47                                 int                                 TempVar                             -1                                  -1
1                                   T50                                 TempVarType                         TempVar                             -1                                  -1
1                                   T51                                 TempVarType                         TempVar                             -1                                  -1
1                                   T52                                 int                                 TempVar                             -1                                  -1
1                                   T55                                 TempVarType                         TempVar                             -1                                  -1
1                                   T58                                 TempVarType                         TempVar                             -1                                  -1
1                                   T62                                 TempVarType                         TempVar                             -1                                  -1
1                                   T63                                 bool                                TempVar                             -1                                  -1
1                                   T65                                 TempVarType                         TempVar                             -1                                  -1
1                                   T66                                 bool                                TempVar                             -1                                  -1
1                                   T67                                 bool                                TempVar                             -1                                  -1
1                                   L0                                  N/A                                 TempLabel                           -1                                  -1
1                                   T68                                 TempVarType                         TempVar                             -1                                  -1
1                                   T71                                 TempVarType                         TempVar                             -1                                  -1
1                                   L1                                  N/A                                 TempLabel                           -1                                  -1
1                                   T81                                 TempVarType                         TempVar                             -1                                  -1
1                                   T82                                 bool                                TempVar                             -1                                  -1
1                                   T93                                 TempVarType                         TempVar                             -1                                  -1
1                                   L4                                  N/A                                 TempLabel                           -1                                  -1
1                                   T145                                bool                                TempVar                             -1                                  -1
1                                   L5                                  N/A                                 TempLabel                           -1                                  -1
1                                   T94                                 TempVarType                         TempVar                             -1                                  -1
1                                   T146                                bool                                TempVar                             -1                                  -1
1                                   T95                                 TempVarType                         TempVar                             -1                                  -1
1                                   T138                                bool                                TempVar                             -1                                  -1
1                                   T96                                 TempVarType                         TempVar                             -1                                  -1
1                                   T139                                bool                                TempVar                             -1                                  -1
1                                   T97                                 TempVarType                         TempVar                             -1                                  -1
1                                   T131                                bool                                TempVar                             -1                                  -1
1                                   T98                                 TempVarType                         TempVar                             -1                                  -1
1                                   T132                                bool                                TempVar                             -1                                  -1
1                                   T99                                 TempVarType                         TempVar                             -1                                  -1
1                                   T102                                TempVarType                         TempVar                             -1                                  -1
1                                   T123                                bool                                TempVar                             -1                                  -1
1                                   T103                                TempVarType                         TempVar                             -1                                  -1
1                                   T124                                bool                                TempVar                             -1                                  -1
1                                   T104                                TempVarType                         TempVar                             -1                                  -1
1                                   T107                                TempVarType                         TempVar                             -1                                  -1
1                                   T115                                bool                                TempVar                             -1                                  -1
1                                   T108                                TempVarType                         TempVar                             -1                                  -1
1                                   T116                                bool                                TempVar                             -1                                  -1
4                                   bar                                 func                                Func_Name                           5                                   5
9                                   False                               bool                                Constant                            6                                   6
9                                   q                                   bool                                Identifier                          6                                   6
9                                   "stringify"                         str                                 Constant                            7                                   7
9                                   r                                   str                                 Identifier                          7                                   7
9                                   bar                                 func                                Func_Name                           8                                   8
16                                  "function"                          str                                 Constant                            9                                   9
```

TAC-

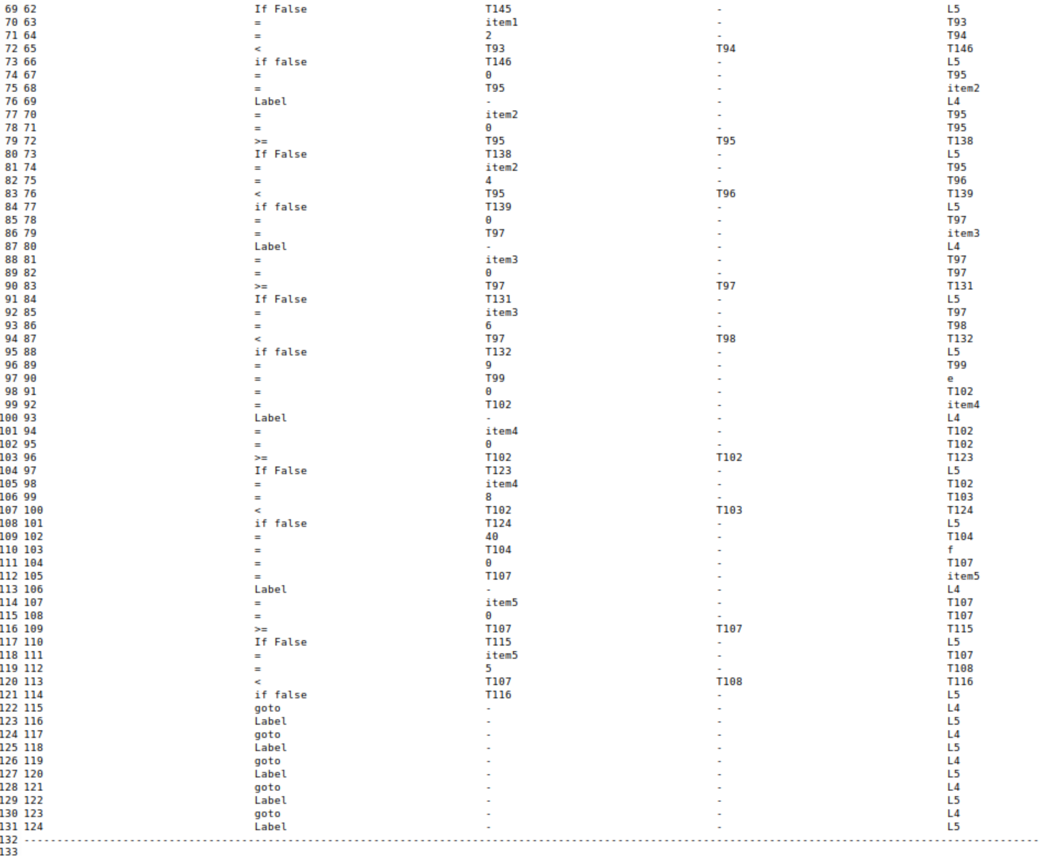


```
------------------------------------------------------------Three Address Code------------------------------------------------------------
import mymodule
Begin Function foo
Begin Function bar
T4 = False
q = T4
T7 = "stringify"
r = T7
Begin Function bar
End Function bar
End Function bar
End Function foo
(T30)Call Function foo
T31 = True
x = T31
T34 = "this is a string"
z = T34
T37 = 3
T38 = 4
T39 = T37 * T38
c = T39
T42 = 10
s = T42
T42 = s
T42 = s
T47 = T42 + T42
t = T47
T50 = 100
T51 = 15
T52 = T50 + T51
u = T52
T55 = 5
a = T55
T58 = 10
b = T58
T55 = a
T62 = 5
T63 = T55 == T62
T58 = b
T65 = 8
T66 = T58 > T65
T67 = T63 and T66
If False T67 goto L0
T68 = 9
a = T68
T71 = 20
b = T71
goto L1
L0: T55 = a
T81 = 4
T82 = T55 < T81
If False T82 goto L0
goto L1
L0: L1: L1: T93 = 0
item1 = T93

L4: T93 = item1
T93 = 0
T145 = T93 >= T93
If False T145 goto L5
T93 = item1
T94 = 2
T146 = T93 < T94
If False T146 goto L5
T95 = 0
item2 = T95

L4: T95 = item2
T95 = 0
T138 = T95 >= T95
If False T138 goto L5
T95 = item2
T96 = 4
T139 = T95 < T96
If False T139 goto L5
T97 = 0
item3 = T97

L4: T97 = item3
T97 = 0
T131 = T97 >= T97
If False T131 goto L5
T97 = item3
T98 = 6
T132 = T97 < T98
If False T132 goto L5
T99 = 9
e = T99
T102 = 0
item4 = T102

L4: T102 = item4
T102 = 0
T123 = T102 >= T102
If False T123 goto L5
T102 = item4
T103 = 8
T124 = T102 < T103
If False T124 goto L5
T104 = 40
f = T104
T107 = 0
item5 = T107

L4: T107 = item5
T107 = 0
T115 = T107 >= T107
If False T115 goto L5
T107 = item5
T108 = 5
T116 = T107 < T108
If False T116 goto L5
goto L4
L5: goto L4
L5: goto L4
L5: goto L4
L5: goto L4
L5:
```

Quads (before optimisation)-

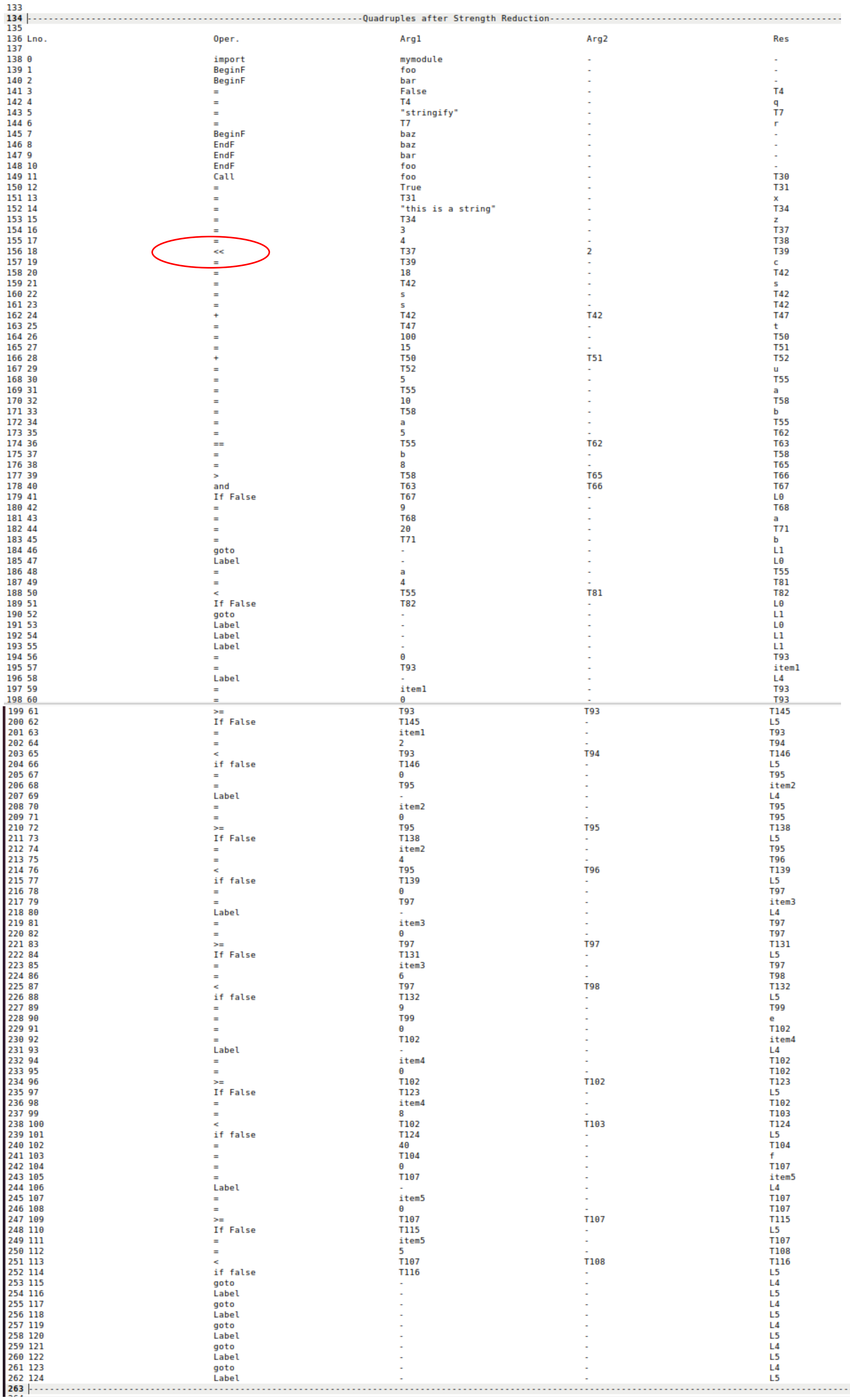


```
--------------------------------------------------------------------------------------------------------

--------------------------------------------Quadruples --------------------------------------------

Lno.          Oper.          Arg1                   Arg2          Res

0             import         mymodule               -             -
1             BeginF         foo                    -             -
2             BeginF         bar                    -             -
3             =              False                  -             T4
4             =              T4                     -             q
5             =              "stringify"            -             T7
6             =              T7                     -             r
7             BeginF         baz                    -             -
8             EndF           baz                    -             -
9             EndF           bar                    -             -
10            EndF           foo                    -             -
11            Call           foo                    -             T30
12            =              True                   -             T31
13            =              T31                    -             x
14            =              "this is a string"     -             T34
15            =              T34                    -             z
16            =              3                      -             T37
17            =              4                      -             T38
18            *              T37                    T38           T39
19            =              T39                    -             c
20            =              18                     -             T42
21            =              T42                    -             s
22            =              s                      -             T42
23            =              s                      -             T42
24            +              T42                    T42           T47
25            =              T47                    -             t
26            =              100                    -             T50
27            =              15                     -             T51
28            +              T50                    T51           T52
29            =              T52                    -             u
30            =              5                      -             T55
31            =              T55                    -             a
32            =              10                     -             T58
33            =              T58                    -             b
34            =              a                      -             T55
35            =              5                      -             T62
36            ==             T55                    T62           T63
37            =              b                      -             T58
38            =              8                      -             T65
39            >              T58                    T65           T66
40            and            T63                    T66           T67
41            If False       T67                    -             L0
42            =              9                      -             T68
43            =              T68                    -             a
44            =              20                     -             T71
45            =              T71                    -             b
46            goto           -                      -             L1
47            Label          -                      -             L0
48            =              a                      -             T55
49            =              4                      -             T81
50            <              T55                    T81           T82
51            If False       T82                    -             L0
52            goto           -                      -             L1
53            Label          -                      -             L0
54            Label          -                      -             L1
55            Label          -                      -             L1
56            =              0                      -             T93
57            =              T93                    -             item1
58            Label          -                      -             L4
59            =              item1                  -             T93
60            =              0                      -             T93
61            >=             T93                    T93           T145
```



```
62            If False       T145                   -             L5
63            =              item1                  -             T93
64            =              2                      -             T94
65            <              T93                    T94           T146
66            if false       T146                   -             L5
67            =              0                      -             T95
68            =              T95                    -             item2
69            Label          -                      -             L4
70            =              item2                  -             T95
71            =              0                      -             T95
72            >=             T95                    T95           T138
73            If False       T138                   -             L5
74            =              item2                  -             T95
75            =              4                      -             T96
76            <              T95                    T96           T139
77            if false       T139                   -             L5
78            =              0                      -             T97
79            =              T97                    -             item3
80            Label          -                      -             L4
81            =              item3                  -             T97
82            =              0                      -             T97
83            >=             T97                    T97           T131
84            If False       T131                   -             L5
85            =              item3                  -             T97
86            =              6                      -             T98
87            <              T97                    T98           T132
88            if false       T132                   -             L5
89            =              9                      -             T99
90            =              T99                    -             e
91            =              0                      -             T102
92            =              T102                   -             item4
93            Label          -                      -             L4
94            =              item4                  -             T102
95            =              0                      -             T102
96            >=             T102                   T102          T123
97            If False       T123                   -             L5
98            =              item4                  -             T102
99            =              8                      -             T103
100           <              T102                   T103          T124
101           if false       T124                   -             L5
102           =              40                     -             T104
103           =              T104                   -             f
104           =              0                      -             T107
105           =              T107                   -             item5
106           Label          -                      -             L4
107           =              item5                  -             T107
108           =              0                      -             T107
109           >=             T107                   T107          T115
110           If False       T115                   -             L5
111           =              item5                  -             T107
112           =              5                      -             T108
113           <              T107                   T108          T116
114           if false       T116                   -             L5
115           goto           -                      -             L4
116           Label          -                      -             L5
117           goto           -                      -             L4
118           Label          -                      -             L5
119           goto           -                      -             L4
120           Label          -                      -             L5
121           goto           -                      -             L4
122           Label          -                      -             L5
123           goto           -                      -             L4
124           Label          -                      -             L5
--------------------------------------------------------------------------------------------------------
```

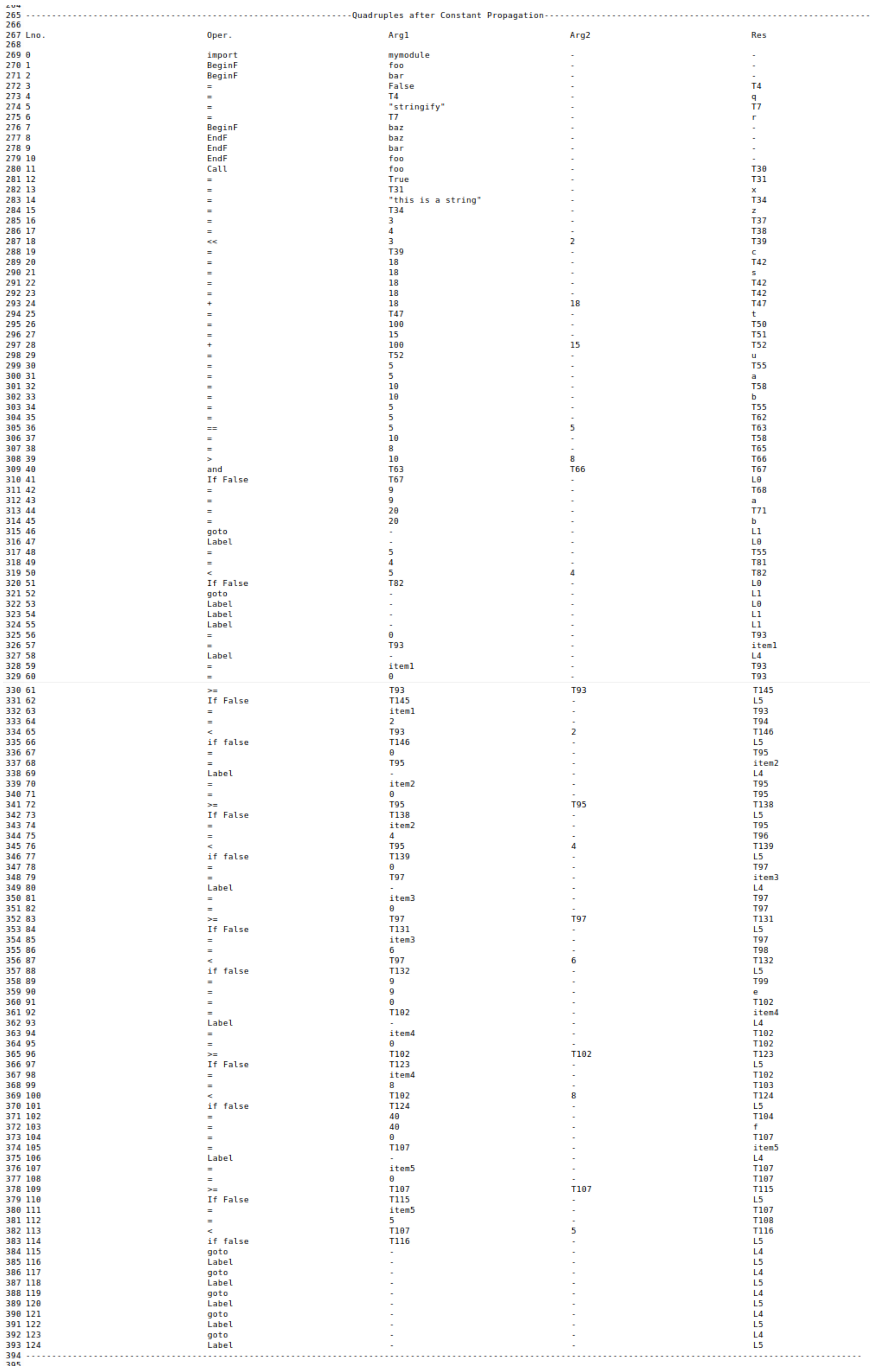
Quads (after strength reduction)-



```
-----------------------------Quadruples after Strength Reduction-----------------------------

Lno.            Oper.           Arg1                Arg2      Res

0               import          mymodule            -         -
1               BeginF          foo                 -         -
2               BeginF          bar                 -         -
3               =               False               -         T4
4               =               T4                  -         q
5               =               "stringify"         -         T7
6               =               T7                  -         r
7               BeginF          baz                 -         -
8               EndF            baz                 -         -
9               EndF            bar                 -         -
10              EndF            foo                 -         -
11              Call            foo                 -         T30
12              =               True                -         T31
13              =               T31                 -         x
14              =               "this is a string"  -         T34
15              =               T34                 -         z
16              =               3                   -         T37
17              =               4                   -         T38
18              <<              T37                 2         T39
19              =               T39                 -         c
20              =               18                  -         T42
21              =               T42                 -         s
22              =               s                   -         T42
23              =               s                   -         T42
24              +               T42                 T42       T47
25              =               T47                 -         t
26              =               100                 -         T50
27              =               15                  -         T51
28              +               T50                 T51       T52
29              =               T52                 -         u
30              =               5                   -         T55
31              =               T55                 -         a
32              =               10                  -         T58
33              =               T58                 -         b
34              =               a                   -         T55
35              =               5                   -         T62
36              ==              T55                 T62       T63
37              =               b                   -         T58
38              =               8                   -         T65
39              >               T58                 T65       T66
40              and             T63                 T66       T67
41              If False        T67                 -         L0
42              =               9                   -         T68
43              =               T68                 -         a
44              =               20                  -         T71
45              =               T71                 -         b
46              goto            -                   -         L1
47              Label           -                   -         L0
48              =               a                   -         T55
49              =               4                   -         T81
50              <               T55                 T81       T82
51              If False        T82                 -         L0
52              goto            -                   -         L1
53              Label           -                   -         L0
54              Label           -                   -         L1
55              Label           -                   -         L1
56              =               0                   -         T93
57              =               T93                 -         item1
58              Label           -                   -         L4
59              =               item1               -         T93
60              =               0                   -         T93
61              >=              T93                 T93       T145
62              If False        T145                -         L5
63              =               item1               -         T93
64              =               2                   -         T94
65              <               T93                 T94       T146
66              if false        T146                -         L5
67              =               0                   -         T95
68              =               T95                 -         item2
69              Label           -                   -         L4
70              =               item2               -         T95
71              =               0                   -         T95
72              >=              T95                 T95       T138
73              If False        T138                -         L5
74              =               item2               -         T95
75              =               4                   -         T96
76              <               T95                 T96       T139
77              if false        T139                -         L5
78              =               0                   -         T97
79              =               T97                 -         item3
80              Label           -                   -         L4
81              =               item3               -         T97
82              =               0                   -         T97
83              >=              T97                 T97       T131
84              If False        T131                -         L5
85              =               item3               -         T97
86              =               6                   -         T98
87              <               T97                 T98       T132
88              if false        T132                -         L5
89              =               9                   -         T99
90              =               T99                 -         e
91              =               0                   -         T102
92              =               T102                -         item4
93              Label           -                   -         L4
94              =               item4               -         T102
95              =               0                   -         T102
96              >=              T102                T102      T123
97              If False        T123                -         L5
98              =               item4               -         T102
99              =               8                   -         T103
100             <               T102                T103      T124
101             if false        T124                -         L5
102             =               40                  -         T104
103             =               T104                -         f
104             =               0                   -         T107
105             =               T107                -         item5
106             Label           -                   -         L4
107             =               item5               -         T107
108             =               0                   -         T107
109             >=              T107                T107      T115
110             If False        T115                -         L5
111             =               item5               -         T107
112             =               5                   -         T108
113             <               T107                T108      T116
114             if false        T116                -         L5
115             goto            -                   -         L4
116             Label           -                   -         L5
117             goto            -                   -         L4
118             Label           -                   -         L5
119             goto            -                   -         L4
120             Label           -                   -         L5
121             goto            -                   -         L4
122             Label           -                   -         L5
123             goto            -                   -         L4
124             Label           -                   -         L5
---------------------------------------------------------------------------------------------
```

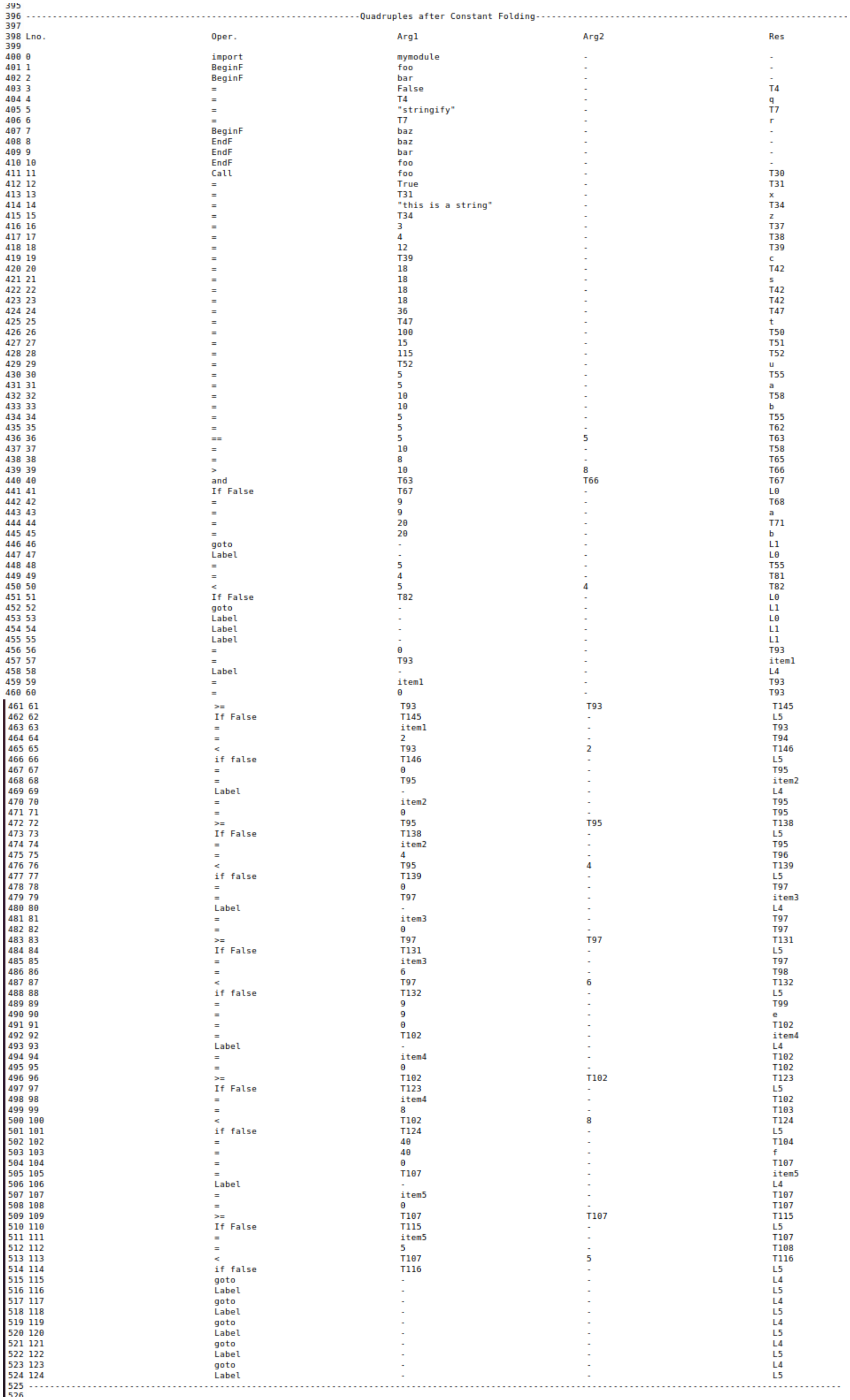
We can see that the * operation has been changed to <<

Quads (after constant propagation)-



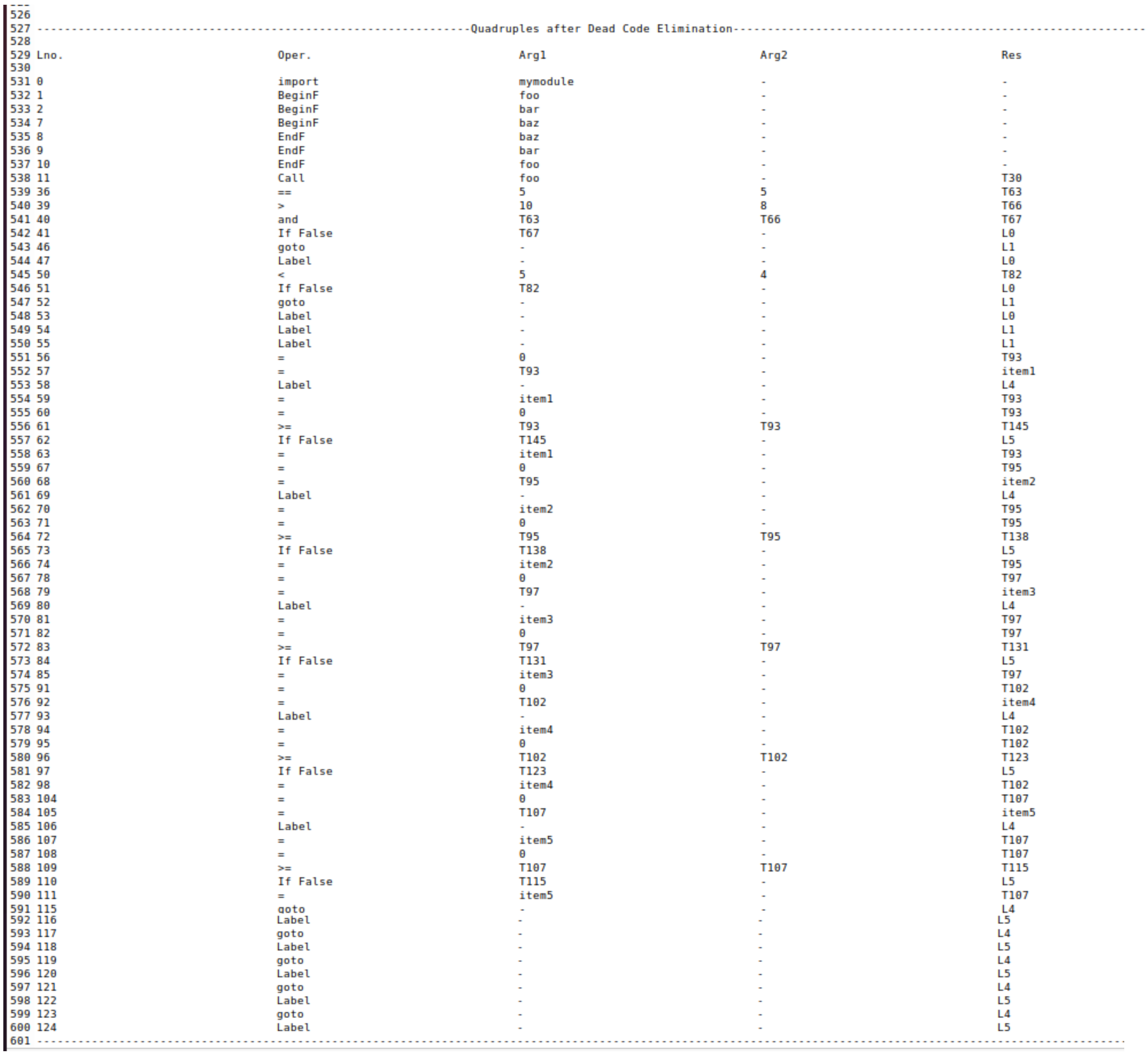
```
---------------------------------------------------------------Quadruples after Constant Propagation--------------------------------------------------------------

Lno.                Oper.               Arg1                Arg2                Res

0                   import              mymodule            -                   -
1                   BeginF              foo                 -                   -
2                   BeginF              bar                 -                   -
3                   =                   False               -                   T4
4                   =                   T4                  -                   q
5                   =                   "stringify"         -                   T7
6                   =                   T7                  -                   r
7                   BeginF              baz                 -                   -
8                   EndF                baz                 -                   -
9                   EndF                bar                 -                   -
10                  EndF                foo                 -                   -
11                  Call                foo                 -                   T30
12                  =                   True                -                   T31
13                  =                   T31                 -                   x
14                  =                   "this is a string"  -                   T34
15                  =                   T34                 -                   z
16                  =                   3                   -                   T37
17                  =                   4                   -                   T38
18                  <<                  3                   2                   T39
19                  =                   T39                 -                   c
20                  =                   18                  -                   T42
21                  =                   18                  -                   s
22                  =                   18                  -                   T42
23                  =                   18                  -                   T42
24                  +                   18                  18                  T47
25                  =                   T47                 -                   t
26                  =                   100                 -                   T50
27                  =                   15                  -                   T51
28                  +                   100                 15                  T52
29                  =                   T52                 -                   u
30                  =                   5                   -                   T55
31                  =                   5                   -                   a
32                  =                   10                  -                   T58
33                  =                   10                  -                   b
34                  =                   5                   -                   T55
35                  =                   5                   -                   T62
36                  ==                  5                   5                   T63
37                  =                   10                  -                   T58
38                  =                   8                   -                   T65
39                  >                   10                  8                   T66
40                  and                 T63                 T66                 T67
41                  If False            T67                 -                   L0
42                  =                   9                   -                   T68
43                  =                   9                   -                   a
44                  =                   20                  -                   T71
45                  =                   20                  -                   b
46                  goto                -                   -                   L1
47                  Label               -                   -                   L0
48                  =                   5                   -                   T55
49                  =                   4                   -                   T81
50                  <                   5                   4                   T82
51                  If False            T82                 -                   L0
52                  goto                -                   -                   L1
53                  Label               -                   -                   L0
54                  Label               -                   -                   L1
55                  Label               -                   -                   L1
56                  =                   0                   -                   T93
57                  =                   T93                 -                   item1
58                  Label               -                   -                   L4
59                  =                   item1               -                   T93
60                  =                   0                   -                   T93
61                  >=                  T93                 T93                 T145
62                  If False            T145                -                   L5
63                  =                   item1               -                   T93
64                  =                   2                   -                   T94
65                  <                   T93                 2                   T146
66                  if false            T146                -                   L5
67                  =                   0                   -                   T95
68                  =                   T95                 -                   item2
69                  Label               -                   -                   L4
70                  =                   item2               -                   T95
71                  =                   0                   -                   T95
72                  >=                  T95                 T95                 T138
73                  If False            T138                -                   L5
74                  =                   item2               -                   T95
75                  =                   4                   -                   T96
76                  <                   T95                 4                   T139
77                  if false            T139                -                   L5
78                  =                   0                   -                   T97
79                  =                   T97                 -                   item3
80                  Label               -                   -                   L4
81                  =                   item3               -                   T97
82                  =                   0                   -                   T97
83                  >=                  T97                 T97                 T131
84                  If False            T131                -                   L5
85                  =                   item3               -                   T97
86                  =                   6                   -                   T98
87                  <                   T97                 6                   T132
88                  if false            T132                -                   L5
89                  =                   9                   -                   T99
90                  =                   9                   -                   e
91                  =                   0                   -                   T102
92                  =                   T102                -                   item4
93                  Label               -                   -                   L4
94                  =                   item4               -                   T102
95                  =                   0                   -                   T102
96                  >=                  T102                T102                T123
97                  If False            T123                -                   L5
98                  =                   item4               -                   T102
99                  =                   8                   -                   T103
100                 <                   T102                8                   T124
101                 if false            T124                -                   L5
102                 =                   40                  -                   T104
103                 =                   40                  -                   f
104                 =                   0                   -                   T107
105                 =                   T107                -                   item5
106                 Label               -                   -                   L4
107                 =                   item5               -                   T107
108                 =                   0                   -                   T107
109                 >=                  T107                T107                T115
110                 If False            T115                -                   L5
111                 =                   item5               -                   T107
112                 =                   5                   -                   T108
113                 <                   T107                5                   T116
114                 if false            T116                -                   L5
115                 goto                -                   -                   L4
116                 Label               -                   -                   L5
117                 goto                -                   -                   L4
118                 Label               -                   -                   L5
119                 goto                -                   -                   L4
120                 Label               -                   -                   L5
121                 goto                -                   -                   L4
122                 Label               -                   -                   L5
123                 goto                -                   -                   L4
124                 Label               -                   -                   L5
-----------------------------------------------------------------------------------------------------------------------------------------------------------------
```

Quads (after constant folding)-



```
------------------------------------------------------------Quadruples after Constant Folding------------------------------------------------------------

Lno.                Oper.               Arg1                  Arg2                Res

0                   import              mymodule              -                   -
1                   BeginF              foo                   -                   -
2                   BeginF              bar                   -                   -
3                   =                   False                 -                   T4
4                   =                   T4                    -                   q
5                   =                   "stringify"           -                   T7
6                   =                   T7                    -                   r
7                   BeginF              baz                   -                   -
8                   EndF                baz                   -                   -
9                   EndF                bar                   -                   -
10                  EndF                foo                   -                   -
11                  Call                foo                   -                   T30
12                  =                   True                  -                   T31
13                  =                   T31                   -                   x
14                  =                   "this is a string"    -                   T34
15                  =                   T34                   -                   z
16                  =                   3                     -                   T37
17                  =                   4                     -                   T38
18                  =                   12                    -                   T39
19                  =                   T39                   -                   c
20                  =                   18                    -                   T42
21                  =                   18                    -                   s
22                  =                   18                    -                   T42
23                  =                   18                    -                   T42
24                  =                   36                    -                   T47
25                  =                   T47                   -                   t
26                  =                   100                   -                   T50
27                  =                   15                    -                   T51
28                  =                   115                   -                   T52
29                  =                   T52                   -                   u
30                  =                   5                     -                   T55
31                  =                   5                     -                   a
32                  =                   10                    -                   T58
33                  =                   10                    -                   b
34                  =                   5                     -                   T55
35                  =                   5                     -                   T62
36                  ==                  5                     5                   T63
37                  =                   10                    -                   T58
38                  =                   8                     -                   T65
39                  >                   10                    8                   T66
40                  and                 T63                   T66                 T67
41                  If False            T67                   -                   L0
42                  =                   9                     -                   T68
43                  =                   9                     -                   a
44                  =                   20                    -                   T71
45                  =                   20                    -                   b
46                  goto                -                     -                   L1
47                  Label               -                     -                   L0
48                  =                   5                     -                   T55
49                  =                   4                     -                   T81
50                  <                   5                     4                   T82
51                  If False            T82                   -                   L0
52                  goto                -                     -                   L1
53                  Label               -                     -                   L0
54                  Label               -                     -                   L1
55                  Label               -                     -                   L1
56                  =                   0                     -                   T93
57                  =                   T93                   -                   item1
58                  Label               -                     -                   L4
59                  =                   item1                 -                   T93
60                  =                   0                     -                   T93
61                  >=                  T93                   T93                 T145
62                  If False            T145                  -                   L5
63                  =                   item1                 -                   T93
64                  =                   2                     -                   T94
65                  <                   T93                   2                   T146
66                  if false            T146                  -                   L5
67                  =                   0                     -                   T95
68                  =                   T95                   -                   item2
69                  Label               -                     -                   L4
70                  =                   item2                 -                   T95
71                  =                   0                     -                   T95
72                  >=                  T95                   T95                 T138
73                  If False            T138                  -                   L5
74                  =                   item2                 -                   T95
75                  =                   4                     -                   T96
76                  <                   T95                   4                   T139
77                  if false            T139                  -                   L5
78                  =                   0                     -                   T97
79                  =                   T97                   -                   item3
80                  Label               -                     -                   L4
81                  =                   item3                 -                   T97
82                  =                   0                     -                   T97
83                  >=                  T97                   T97                 T131
84                  If False            T131                  -                   L5
85                  =                   item3                 -                   T97
86                  =                   6                     -                   T98
87                  <                   T97                   6                   T132
88                  if false            T132                  -                   L5
89                  =                   9                     -                   T99
90                  =                   9                     -                   e
91                  =                   0                     -                   T102
92                  =                   T102                  -                   item4
93                  Label               -                     -                   L4
94                  =                   item4                 -                   T102
95                  =                   0                     -                   T102
96                  >=                  T102                  T102                T123
97                  If False            T123                  -                   L5
98                  =                   item4                 -                   T102
99                  =                   8                     -                   T103
100                 <                   T102                  8                   T124
101                 if false            T124                  -                   L5
102                 =                   40                    -                   T104
103                 =                   40                    -                   f
104                 =                   0                     -                   T107
105                 =                   T107                  -                   item5
106                 Label               -                     -                   L4
107                 =                   item5                 -                   T107
108                 =                   0                     -                   T107
109                 >=                  T107                  T107                T115
110                 If False            T115                  -                   L5
111                 =                   item5                 -                   T107
112                 =                   5                     -                   T108
113                 <                   T107                  5                   T116
114                 if false            T116                  -                   L5
115                 goto                -                     -                   L4
116                 Label               -                     -                   L5
117                 goto                -                     -                   L4
118                 Label               -                     -                   L5
119                 goto                -                     -                   L4
120                 Label               -                     -                   L5
121                 goto                -                     -                   L4
122                 Label               -                     -                   L5
123                 goto                -                     -                   L4
124                 Label               -                     -                   L5
---------------------------------------------------------------------------------------------------------------------------------------------------------
```

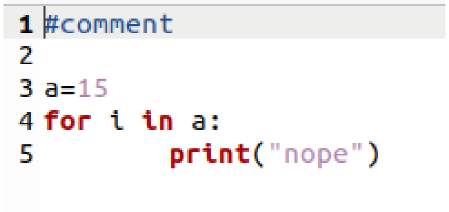
Quads (after dead code elimination)-



```

------------------------------------------------------------Quadruples after Dead Code Elimination------------------------------------------------------------

Lno.                              Oper.                             Arg1                              Arg2                              Res

0                                 import                            mymodule                          -                                 -
1                                 BeginF                            foo                               -                                 -
2                                 BeginF                            bar                               -                                 -
7                                 BeginF                            baz                               -                                 -
8                                 EndF                              baz                               -                                 -
9                                 EndF                              bar                               -                                 -
10                                EndF                              foo                               -                                 -
11                                Call                              foo                               -                                 T30
36                                ==                                5                                 5                                 T63
39                                >                                 10                                8                                 T66
40                                and                               T63                               T66                               T67
41                                If False                          T67                               -                                 L0
46                                goto                              -                                 -                                 L1
47                                Label                             -                                 -                                 L0
50                                <                                 5                                 4                                 T82
51                                If False                          T82                               -                                 L0
52                                goto                              -                                 -                                 L1
53                                Label                             -                                 -                                 L0
54                                Label                             -                                 -                                 L1
55                                Label                             -                                 -                                 L1
56                                =                                 0                                 -                                 T93
57                                =                                 T93                               -                                 item1
58                                Label                             -                                 -                                 L4
59                                =                                 item1                             -                                 T93
60                                =                                 0                                 -                                 T93
61                                >=                                T93                               T93                               T145
62                                If False                          T145                              -                                 L5
63                                =                                 item1                             -                                 T93
67                                =                                 0                                 -                                 T95
68                                =                                 T95                               -                                 item2
69                                Label                             -                                 -                                 L4
70                                =                                 item2                             -                                 T95
71                                =                                 0                                 -                                 T95
72                                >=                                T95                               T95                               T138
73                                If False                          T138                              -                                 L5
74                                =                                 item2                             -                                 T95
78                                =                                 0                                 -                                 T97
79                                =                                 T97                               -                                 item3
80                                Label                             -                                 -                                 L4
81                                =                                 item3                             -                                 T97
82                                =                                 0                                 -                                 T97
83                                >=                                T97                               T97                               T131
84                                If False                          T131                              -                                 L5
85                                =                                 item3                             -                                 T97
91                                =                                 0                                 -                                 T102
92                                =                                 T102                              -                                 item4
93                                Label                             -                                 -                                 L4
94                                =                                 item4                             -                                 T102
95                                =                                 0                                 -                                 T102
96                                >=                                T102                              T102                              T123
97                                If False                          T123                              -                                 L5
98                                =                                 item4                             -                                 T102
104                               =                                 0                                 -                                 T107
105                               =                                 T107                              -                                 item5
106                               Label                             -                                 -                                 L4
107                               =                                 item5                             -                                 T107
108                               =                                 0                                 -                                 T107
109                               >=                                T107                              T107                              T115
110                               If False                          T115                              -                                 L5
111                               =                                 item5                             -                                 T107
115                               goto                              -                                 -                                 L4
116                               Label                             -                                 -                                 L5
117                               goto                              -                                 -                                 L4
118                               Label                             -                                 -                                 L5
119                               goto                              -                                 -                                 L4
120                               Label                             -                                 -                                 L5
121                               goto                              -                                 -                                 L4
122                               Label                             -                                 -                                 L5
123                               goto                              -                                 -                                 L4
124                               Label                             -                                 -                                 L5
--------------------------------------------------------------------------------------------------------------------------------------------------------------
```

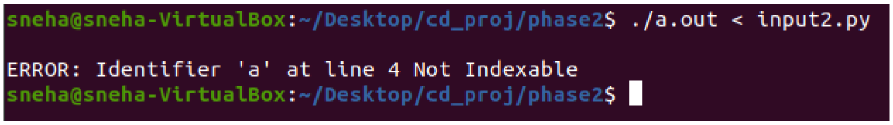
Test file 2-

- Input-



```
1 #comment
2
3 a=15
4 for i in a:
5         print("nope")
```

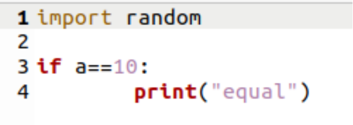
- Output-



```
sneha@sneha-VirtualBox:~/Desktop/cd_proj/phase2$ ./a.out < input2.py

ERROR: Identifier 'a' at line 4 Not Indexable
sneha@sneha-VirtualBox:~/Desktop/cd_proj/phase2$ 
```

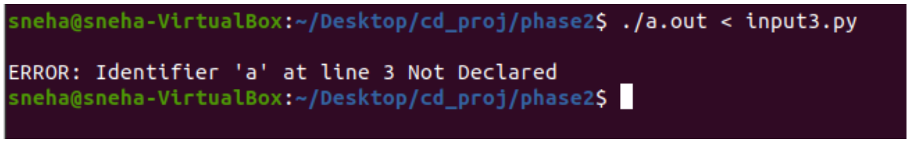
Test file 3-

- Input-



```
1 import random
2
3 if a==10:
4         print("equal")
```

- Output-



```
sneha@sneha-VirtualBox:~/Desktop/cd_proj/phase2$ ./a.out < input3.py

ERROR: Identifier 'a' at line 3 Not Declared
sneha@sneha-VirtualBox:~/Desktop/cd_proj/phase2$ 
```

CONCLUSION

We were able to successfully design and implement a mini-compiler for the “if-else” and “for” constructs of Python. In the process, we gained a better insight on how compilers work, and their various phases.