Assembler:

```
import java.io.BufferedReader;
import java.io.FileReader;
import java.io.FileWriter;
import java.io.IOException;
import java.io.FileWriter;
import java.util.*;

public class assembler {

    static String C2Binary(String instruction){

        HashMap<String, String> destDict = new HashMap<>();
        destDict.put("", "000");
        destDict.put("M", "001");
        destDict.put("D", "010");
        destDict.put("MD", "011");
        destDict.put("A", "100");
        destDict.put("AM", "101");
        destDict.put("AD", "110");
        destDict.put("AMD", "111");

        HashMap<String, String> compDict = new HashMap<>();
        compDict.put("0", "0101010");
        compDict.put("1", "0111111");
        compDict.put("-1", "0111010");
        compDict.put("D", "0001100");
        compDict.put("A", "0110000");
        compDict.put("!D", "0001101");
        compDict.put("!A", "0110001");
        compDict.put("-D", "0001111");
        compDict.put("-A", "0110011");
        compDict.put("D+1", "0011111");
        compDict.put("A+1", "0110111");
        compDict.put("D-1", "0001110");
        compDict.put("A-1", "0110010");
        compDict.put("D+A", "0000010");
        compDict.put("A+D", "0000010");
        compDict.put("D-A", "0010011");
        compDict.put("A-D", "0000111");
        compDict.put("D&A", "0000000");
        compDict.put("A&D", "0000000");
        compDict.put("D|A", "0010101");
        compDict.put("A|D", "0010101");
        compDict.put("M", "1110000");
```

```
        compDict.put("!M", "1110001");
        compDict.put("-M", "1110011");
        compDict.put("M+1", "1110111");
        compDict.put("M-1", "1110010");
        compDict.put("D+M", "1000010");
        compDict.put("D-M", "1010011");
        compDict.put("M-D", "1000111");
        compDict.put("D&M", "1000000");
        compDict.put("C|M", "1010101");

        HashMap<String, String> jumpDict = new HashMap<>();
        jumpDict.put("", "000");
        jumpDict.put("JGT", "001");
        jumpDict.put("JEQ", "010");
        jumpDict.put("JGE", "011");
        jumpDict.put("JLT", "100");
        jumpDict.put("JNE", "101");
        jumpDict.put("JLE", "110");
        jumpDict.put("JMP", "111");

        String[] destAndCompJump = instruction.split("=");
        String dest = destAndCompJump.length > 1 ?
destAndCompJump[0] : "";
        String compJump = destAndCompJump[destAndCompJump.length -
1];
        String[] compAndJump = compJump.split(";");
        String comp = compAndJump[0];
        String jump = compAndJump.length > 1 ? compAndJump[1] : "";
        String binary = "111" + compDict.get(comp)
+  destDict.get(dest) +jumpDict.get(jump);

        return binary;
    }

    public static void main(String[] args) throws IOException {

        BufferedReader reader = new BufferedReader(new
FileReader("Rect.asm"));
        List<String> lines = new ArrayList<>();
        String line = reader.readLine();

        while (line != null) {
            lines.add(line);
            line = reader.readLine();
        }
        reader.close();
```

```
ArrayList<String> preDefinedSymbols = new ArrayList();
preDefinedSymbols.add("R0");
preDefinedSymbols.add("R1");
preDefinedSymbols.add("R2");
preDefinedSymbols.add("R3");
preDefinedSymbols.add("R4");
preDefinedSymbols.add("R5");
preDefinedSymbols.add("R6");
preDefinedSymbols.add("R7");
preDefinedSymbols.add("R8");
preDefinedSymbols.add("R9");
preDefinedSymbols.add("R10");
preDefinedSymbols.add("R11");
preDefinedSymbols.add("R12");
preDefinedSymbols.add("R13");
preDefinedSymbols.add("R14");
preDefinedSymbols.add("R15");

HashMap<String, Integer> unqLbls = new HashMap<>();
unqLbls.put("SCREEN", 16384);
unqLbls.put("KBD", 24576);
unqLbls.put("SP", 0);
unqLbls.put("LCL", 1);
unqLbls.put("ARG", 2);
unqLbls.put("THIS", 3);
unqLbls.put("THAT", 4);

ArrayList<String> symnVar = new ArrayList<>();
ArrayList<String> noWhiteSpace = new ArrayList<>();
ArrayList<String> noLblBrackets = new ArrayList<>();
ArrayList<String> labels = new ArrayList<>();
ArrayList<String> aInstructions = new ArrayList<>();
ArrayList<String> modifiedNoWhiteSpace = new ArrayList<>();
ArrayList<String> hackFile = new ArrayList<>();

HashMap<String, Integer> symbolTable = new HashMap<>();

ArrayList<String> numbersForAins = new ArrayList<>();
for (int i = 0; i < 32768; i++) {
    numbersForAins.add(Integer.toString(i));
}

for (String l : lines) {
    String v;
    if (l.equals("")) continue;
    if (l.contains(" ")) l=l.replace(" ", "");
    if (l.equals("\n") || l.charAt(0) == '/') { continue; }
    else {
```

```
                l = l.replaceAll("[\\n\\t\\s]", "");
                if (l.indexOf("/") != -1) { v = l.substring(0,
l.indexOf("/"));}
                else { v = l; }
            }
            noWhiteSpace.add(v);
        }

        // System.out.println(noWhiteSpace);

        for (String s : noWhiteSpace) {
            s = s.replaceAll("[\\[\\]\\(\\)\\'\\ ]", "");
            noLblBrackets.addAll(Arrays.asList(s.split(",")));
        }

        // System.out.println(noLblBrackets);

        int lbl=0;
        for(String s : noWhiteSpace){
            if (s.charAt(0)=='('){
                s = s.replace("(", "");
                s = s.replace(")","");
                labels.add(lbl, s);
                lbl += 1;
            }
        }

        // System.out.println(labels);

        for (String s : noWhiteSpace){
            if (s.charAt(0)=='@'){
                s = s.replace("@", "");
                if (!Arrays.asList(aInstructions).contains(s)) {
                    aInstructions.add(s);
                    if (!numbersForAins.contains(s) &&
!symnVar.contains(s)) {
                        symnVar.add(s);
                    }
                    if (!numbersForAins.contains(s) &&
!labels.contains(s) && !preDefinedSymbols.contains(s) &&
!unqLbls.containsKey(s)){
                        preDefinedSymbols.add(s);
                    }
                }
            }
        }

        // System.out.println(preDefinedSymbols);
```

```
        for (String s : symnVar){
            if (preDefinedSymbols.contains(s)){
                symbolTable.put(s, preDefinedSymbols.indexOf(s));
            }
            if (labels.contains(s)){
                symbolTable.put(s, (noLblBrackets.indexOf(s)-
labels.indexOf(s)));
            }
            if (unqLbls.containsKey(s)){
                int k = (unqLbls.get(s));
                symbolTable.put(s,k);
            }
        }

        // System.out.println(unqLbls);

        // System.out.println(symbolTable);

        for (String s:noWhiteSpace){
            if (s.contains("(")){continue;}
            if (s.contains("@")){
                s = s.replace("@", "");
                if (!numbersForAins.contains(s)){s =
Integer.toString(symbolTable.get(s));}
                int S = Integer.parseInt(s);
                String Bin_a = Integer.toBinaryString(S);
                String Bin_A="";
                for (int i=0;i<16-Bin_a.length();i++){
                    Bin_A = Bin_A+"0";
                }
                Bin_A = Bin_A + Bin_a;
                hackFile.add(Bin_A);
                s = '@' + s;
            }
            else{
                hackFile.add(C2Binary(s).toString());
            }
            modifiedNoWhiteSpace.add(s);
        }

        FileWriter Hfile = new FileWriter("HackFile.hack");
        for(String s :hackFile){
            System.out.println(s);
            Hfile.write(s);
            Hfile.append("\n");
        }
        Hfile.close();;
```

```
    }
}
```

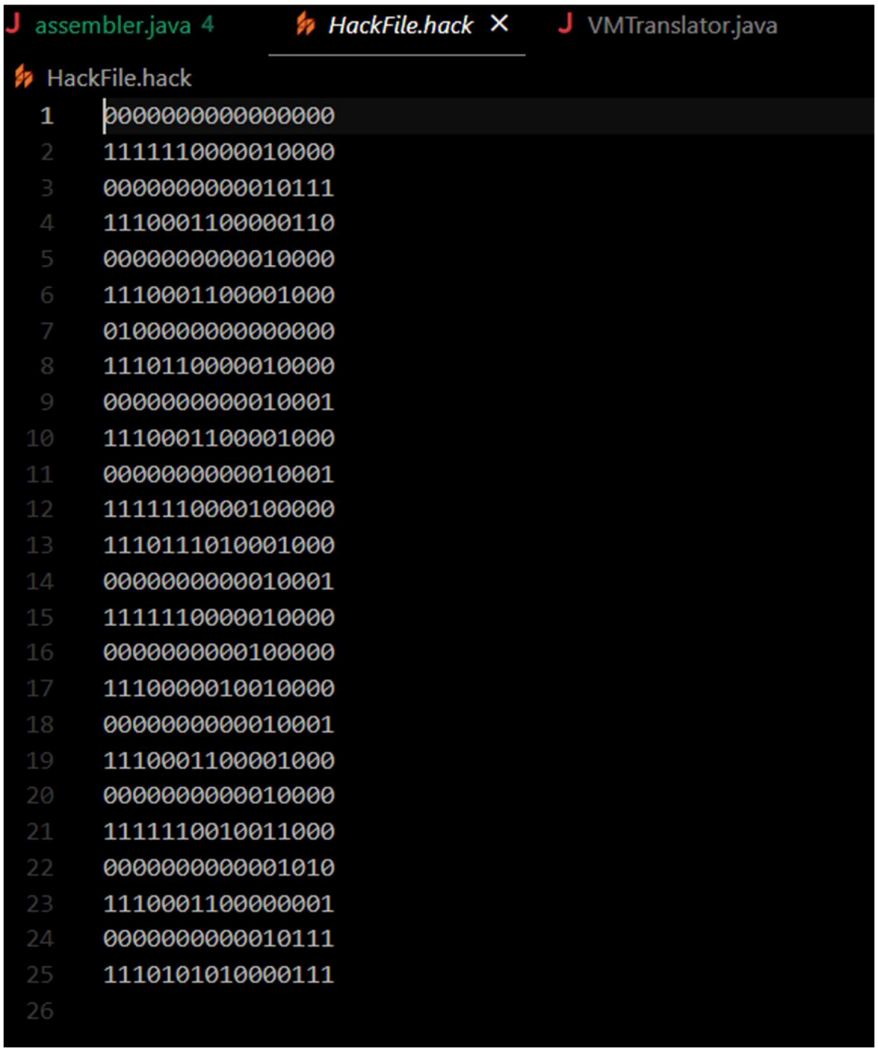
Rect.asm file:

```
// This file is part of www.nand2tetris.org
// and the book "The Elements of Computing Systems"
// by Nisan and Schocken, MIT Press.

// File name: projects/06/rect/Rect.asm
// Draws a rectangle at the top-left corner of the screen.
// The rectangle is 16 pixels wide and R0 pixels high.

   @0
   D=M
   @INFINITE_LOOP
   D;JLE
   @counter
   M=D
   @SCREEN
   D=A
   @address
   M=D
(LOOP)
   @address
   A=M
   M=-1
   @address
   D=M
   @32
   D=D+A
   @address
   M=D
   @counter
   MD=M-1
   @LOOP
   D;JGT
(INFINITE_LOOP)
   @INFINITE_LOOP
   0;JMP
```

Output Hack file:



VM Translator:

Code:

```
import java.io.*;

public class VMTranslator {

    private static int labelCounter = 0;

    private static String pushConstant(String i) {
        String res = "";
        res += "@" + i + "\n";
        res += "D=A" + "\n";
        res += "@SP" + "\n";
        res += "A=M" + "\n";
        res += "M=D" + "\n";
        res += "@SP" + "\n";
        res += "M=M+1" + "\n";
        return res;
    }

    private static String pushStatic(String i) {
        String res = "";
        res += "@" + i + "\n";
        res += "D=M" + "\n";
        res += "@SP" + "\n";
        res += "A=M" + "\n";
        res += "M=D" + "\n";
        res += "@SP" + "\n";
        res += "M=M+1" + "\n";
        return res;
    }

    private static String pushPointer(String i) {
        String res = "";
        if (i.equals("0")) {
            res += "@THIS" + "\n";
        } else if (i.equals("1")) {
            res += "@THAT" + "\n";
        }
        res += "D=M" + "\n";
        res += "@SP" + "\n";
```

```
    res += "A=M" + "\n";
    res += "M=D" + "\n";
    res += "@SP" + "\n";
    res += "M=M+1" + "\n";
    return res;
}

private static String pushSegment(String segment, String i) {
    String res = "";
    res += "@" + i + "\n";
    res += "D=A" + "\n";
    if (segment.equals("local")) {
        res += "@LCL" + "\n";
    } else if (segment.equals("argument")) {
        res += "@ARG" + "\n";
    } else if (segment.equals("this")) {
        res += "@THIS" + "\n";
    } else if (segment.equals("that")) {
        res += "@THAT" + "\n";
    } else if (segment.equals("temp")) {
        res += "@R5" + "\n";
    }
    res += "A=D+M" + "\n";
    res += "D=M" + "\n";
    res += "@SP" + "\n";
    res += "A=M" + "\n";
    res += "M=D" + "\n";
    res += "@SP" + "\n";
    res += "M=M+1" + "\n";
    return res;
}

private static String popStatic(String i) {
    String res = "";
    res += "@SP" + "\n";
    res += "AM=M-1" + "\n";
    res += "D=M" + "\n";
    res += "@" + i + "\n";
    res += "M=D" + "\n";
    return res;
}

private static String popSegment(String segment, String i) {
    String res = "";
    res += "@" + i + "\n";
    res += "D=A" + "\n";
    if (segment.equals("local")) {
        res += "@LCL" + "\n";
```

```
        } else if (segment.equals("argument")) {
            res += "@ARG" + "\n";
        } else if (segment.equals("this")) {
            res += "@THIS" + "\n";
        } else if (segment.equals("that")) {
            res += "@THAT" + "\n";
        } else if (segment.equals("temp")) {
            res += "@R5" + "\n";
        }
        res += "D=D+M" + "\n";
        res += "@R13" + "\n";
        res += "M=D" + "\n";
        res += "@SP" + "\n";
        res += "AM=M-1" + "\n";
        res += "D=M" + "\n";
        res += "@R13" + "\n";
        res += "A=M" + "\n";
        res += "M=D" + "\n";
        return res;
    }

    private static String popPointer(String i) {
        String res = "";
        res += "@SP" + "\n";
        res += "AM=M-1" + "\n";
        res += "D=M" + "\n";
        if (i.equals("0")) {
            res += "@THIS" + "\n";
        } else if (i.equals("1")) {
            res += "@THAT" + "\n";
        }
        res += "M=D" + "\n";
        return res;
    }

    private static String arithSegment(String segment) {
        String res = "";
        if (segment.equals("add")) {
            res += "@SP" + "\n" + "AM=M-1" + "\n" + "D=M" + "\n" +
"A=A-1" + "\n" + "M=M+D" + "\n";
        } else if (segment.equals("sub")) {
            res += "@SP" + "\n" + "AM=M-1" + "\n" + "D=M" + "\n" +
"A=A-1" + "\n" + "M=M-D" + "\n";
        } else if (segment.equals("neg")) {
            res += "@SP" + "\n" + "A=M-1" + "\n" + "M=-M" + "\n";
        } else if (segment.equals("eq")) {
            res += "@SP" + "\n" + "AM=M-1" + "\n" + "D=M" + "\n" +
"A=A-1" + "\n"
```

```
                    + "D=M-D" + "\n" + "@EQ_TRUE" + labelCounter +
"\n" + "D;JEQ" + "\n" + "@SP" + "\n" + "A=M-1" + "\n"
                    + "M=0" + "\n" + "@EQ_END" + labelCounter + "\n"
+ "0;JMP" + "\n" + "(EQ_TRUE" + labelCounter + ")\n"
                    + "@SP" + "\n" + "A=M-1" + "\n" + "M=-1" + "\n"
+ "(EQ_END" + labelCounter + ")\n";
            labelCounter++;
        } else if (segment.equals("gt")) {
            res += "@SP" + "\n" + "AM=M-1" + "\n" + "D=M" + "\n" +
"A=A-1" + "\n"
                    + "D=M-D" + "\n" + "@GT_TRUE" + labelCounter +
"\n" + "D;JGT" + "\n" + "@SP" + "\n" + "A=M-1" + "\n"
                    + "M=0" + "\n" + "@GT_END" + labelCounter + "\n"
+ "0;JMP" + "\n" + "(GT_TRUE" + labelCounter + ")\n"
                    + "@SP" + "\n" + "A=M-1" + "\n" + "M=-1" + "\n"
+ "(GT_END" + labelCounter + ")\n";
            labelCounter++;
        } else if (segment.equals("lt")) {
            res += "@SP" + "\n" + "AM=M-1" + "\n" + "D=M" + "\n" +
"A=A-1" + "\n"
                    + "D=M-D" + "\n" + "@LT_TRUE" + labelCounter +
"\n" + "D;JLT" + "\n" + "@SP" + "\n" + "A=M-1" + "\n"
                    + "M=0" + "\n" + "@LT_END" + labelCounter + "\n"
+ "0;JMP" + "\n" + "(LT_TRUE" + labelCounter + ")\n"
                    + "@SP" + "\n" + "A=M-1" + "\n" + "M=-1" + "\n"
+ "(LT_END" + labelCounter + ")\n";
            labelCounter++;
        } else if (segment.equals("and")) {
            res += "@SP" + "\n" + "AM=M-1" + "\n" + "D=M" + "\n" +
"A=A-1" + "\n" + "M=D&M" + "\n";
        } else if (segment.equals("or")) {
            res += "@SP" + "\n" + "AM=M-1" + "\n" + "D=M" + "\n" +
"A=A-1" + "\n" + "M=D|M" + "\n";
        } else if (segment.equals("not")) {
            res += "@SP" + "\n" + "A=M-1" + "\n" + "M=!M" + "\n";
        }
        return res;
    }

    private static String label(String label) {
        return "(" + label + ")\n";
    }

    private static String gotoLabel(String label) {
        return "@" + label + "\n0;JMP\n";
    }

    private static String ifGotoLabel(String label) {
```

```
        return "@SP\nAM=M-1\nD=M\n@" + label + "\nD;JNE\n";
    }

    public static void main(String[] args) {
        try {
            BufferedReader br = new BufferedReader(new
FileReader("vm.vm"));
            BufferedWriter bw = new BufferedWriter(new
FileWriter("output.asm"));
            String line;
            while ((line = br.readLine()) != null) {
                line = line.trim();

                if (line.isEmpty() || line.startsWith("//")) {
                    continue;
                }

                String[] parts = line.split("\\s+");
                String command = parts[0];
                String arg1 = null;
                String arg2 = null;

                if (parts.length > 1) {
                    arg1 = parts[1];
                }

                if (parts.length > 2) {
                    arg2 = parts[2];
                }

                String asmCode = "";

                if (command.equals("push")) {
                    if (arg1.equals("constant")) {
                        asmCode = pushConstant(arg2);
                    } else if (arg1.equals("static")) {
                        asmCode = pushStatic(arg2);
                    } else if (arg1.equals("pointer")) {
                        asmCode = pushPointer(arg2);
                    } else {
                        asmCode = pushSegment(arg1, arg2);
                    }
                } else if (command.equals("pop")) {
                    if (arg1.equals("static")) {
                        asmCode = popStatic(arg2);
                    } else if (arg1.equals("pointer")) {
                        asmCode = popPointer(arg2);
                    } else {
```

```
                        asmCode = popSegment(arg1, arg2);
                    }
                } else if (command.equals("label")) {
                    asmCode = label(arg1);
                } else if (command.equals("goto")) {
                    asmCode = gotoLabel(arg1);
                } else if (command.equals("if-goto")) {
                    asmCode = ifGotoLabel(arg1);
                } else {
                    asmCode = arithSegment(command);
                }

                bw.write("// " + line + "\n");
                bw.write(asmCode);
            }

            br.close();
            bw.close();
            System.out.println("Translation completed
successfully!");
        } catch (IOException e) {
            e.printStackTrace();
        }
    }
}
```

Input VM file:

vm.vm

```
// This file is part of www.nand2tetris.org
// and the book "The Elements of Computing Systems"
// by Nisan and Schocken, MIT Press.
// File name: projects/07/MemoryAccess/BasicTest/BasicTest.vm

// Executes pop and push commands using the virtual memory segments.
push constant 10
pop local 0
push constant 21
push constant 22
pop argument 2
pop argument 1
push constant 36
pop this 6
push constant 42
push constant 45
pop that 5
pop that 2
push constant 510
pop temp 6
push local 0
push that 5
add
push argument 1
sub
push this 6
push this 6
add
sub
push temp 6
add

```

Output asm file:

```
// push constant 10
@10
D=A
@SP
A=M
M=D
@SP
M=M+1
// pop local 0
@0
D=A
@LCL
D=D+M
@R13
M=D
@SP
AM=M-1
D=M
@R13
A=M
M=D
// push constant 21
@21
D=A
@SP
A=M
M=D
@SP
```

```
M=M+1
// push constant 22
@22
D=A
@SP
A=M
M=D
@SP
M=M+1
// pop argument 2
@2
D=A
@ARG
D=D+M
@R13
M=D
@SP
AM=M-1
D=M
@R13
A=M
M=D
// pop argument 1
@1
D=A
@ARG
D=D+M
@R13
M=D
@SP
```

```
AM=M-1
D=M
@R13
A=M
M=D
// push constant 36
@36
D=A
@SP
A=M
M=D
@SP
M=M+1
// pop this 6
@6
D=A
@THIS
D=D+M
@R13
M=D
@SP
AM=M-1
D=M
@R13
A=M
M=D
// push constant 42
@42
D=A
@SP
```

```
A=M
M=D
@SP
M=M+1
// push constant 45
@45
D=A
@SP
A=M
M=D
@SP
M=M+1
// pop that 5
@5
D=A
@THAT
D=D+M
@R13
M=D
@SP
AM=M-1
D=M
@R13
A=M
M=D
// pop that 2
@2
D=A
@THAT
D=D+M
```

```
@R13
M=D
@SP
AM=M-1
D=M
@R13
A=M
M=D
// push constant 510
@510
D=A
@SP
A=M
M=D
@SP
M=M+1
// pop temp 6
@6
D=A
@R5
D=D+M
@R13
M=D
@SP
AM=M-1
D=M
@R13
A=M
M=D
// push local 0
```

```
@0
D=A
@LCL
A=D+M
D=M
@SP
A=M
M=D
@SP
M=M+1
// push that 5
@5
D=A
@THAT
A=D+M
D=M
@SP
A=M
M=D
@SP
M=M+1
// add
@SP
AM=M-1
D=M
A=A-1
M=M+D
// push argument 1
@1
D=A
```

```
@ARG
A=D+M
D=M
@SP
A=M
M=D
@SP
M=M+1
// sub
@SP
AM=M-1
D=M
A=A-1
M=M-D
// push this 6
@6
D=A
@THIS
A=D+M
D=M
@SP
A=M
M=D
@SP
M=M+1
// push this 6
@6
D=A
@THIS
A=D+M
```

```
D=M
@SP
A=M
M=D
@SP
M=M+1
// add
@SP
AM=M-1
D=M
A=A-1
M=M+D
// sub
@SP
AM=M-1
D=M
A=A-1
M=M-D
// push temp 6
@6
D=A
@R5
A=D+M
D=M
@SP
A=M
M=D
@SP
M=M+1
// add
```

```
@SP
AM=M-1
D=M
A=A-1
M=M+D
```