

# Lab 5 (All Sections) Prelab: Linking

Name:

Sign the following statement:

On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work

## 1 Objective

The main objective of this lab is to understand how a compiler and linker work. Before proceeding with this lab, you should be familiar with relocation entries and compiler operation.

## 2 Introduction

In this lab you will experiment with linking two source files together by using a `gcc` compiler.

### 3 Questions

1. Consider the following three machine instructions, which appear in memory starting at the address 0x00400000.

address (in hex)	contents (in hex)
0x00400000	0x12080002
0x00400004	0x3C11FFFF
0x00400008	0x08100004

- (a) “Disassemble” the instructions; that is, give an assembly language program segment that would be translated into the given machine language.
- (b) You may use numeric rather than symbolic register names.
- (c) Handle branches and jumps specially; where you would normally have a label, provide instead a hexadecimal byte address.

For each of the instructions, indicate whether

- (a) It **MUST** have contributed an entry to the relocation table,
- (b) It **MAY** have contributed an entry to the relocation table, or
- (c) It **COULD NOT** have contributed an entry to the relocation table.

Briefly explain your answers.

2. During which phase of the process from coding to execution do each of the following things happen? Place the most appropriate letter to the answer next to each statement. Some letters may never be used; others may be used more than once.

- The stack pointer decreases;
  - `jr $ra`;
  - Jump statements are resolved;
  - a `jal` instruction is executed;
  - Symbol and relocation tables are created;
  - Machine code is copied from disk into memory;
  - Pseudo-instructions are replaced.
- a) Never
  - b) during loading
  - c) while writing higher-level code
  - d) during the compilation
  - e) during assembly
  - f) during linking
  - g) when `malloc` is called
  - h) when a function is called
  - i) when a function returns
  - j) when registers are spilled

3. Consider the following fragment of MIPS.

```

1      Loop: lui $at, 0xABCD      # a
2      ori $a0,$at, 0xFEDC # b
3      jal add_link      # c
4      bne $a0,$v0, Loop  # d

```

Which of the following instructions may need to be edited during link phase? Explain.

4. Consider the following assembly language program segment:

```

1      funca:
2      la    $t0, n
3      lw    $s0, 0($t0)
4      addi  $s2,$zero,1
5      sub   $s1,$s1,$s1
6      loop:
7      sll   $t0,$s2,31
8      slt   $t1,$t0,$zero
9      bne   $t1,$zero,skip
10     add    $s1,$s1,$s2
11     skip:
12     addi  $s2,$s2,1

```

```
13      beq      $s2, $s0, done
14      j       loop
15      done:
16      addi    $v0, $s1, 0
17      jr      $ra
18
19      n:      .word      11
```

- (a) List instructions that will contribute an entry to the relocation table.

- (b) Substitute all instructions listed in Question 4a to obtain *Position Independent Code* (PIC). Position Independent Code does not have any entries in the relocation table, i.e., it does not have any absolute address.

Hint: substitute all absolute addresses by relative addresses; store all constants directly in the program instead of the data segment.

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5. Assume that a user has many programs; some of them share libraries with each other. The user sometimes runs more than one of these programs at the same time. The users disk is always slower than the users main memory (RAM). For this user compare the performance of “dynamic linking” with “static linking”:
- (a) With respect to the time programs take to start up
  - (b) With respect to required disk space.
  - (c) With respect to the amount of system memory in use at runtime.