null pointer, as required by the C standard. The order ensures that argv[0] is at the lowest virtual address. Word-aligned accesses are faster than unaligned accesses, so for best performance round the stack pointer down to a multiple of 4 before the first push.

Then, push argv (the address of argv[0]) and argc, in that order. Finally, push a fake "return address": although the entry function will never return, its stack frame must have the same structure as any other.

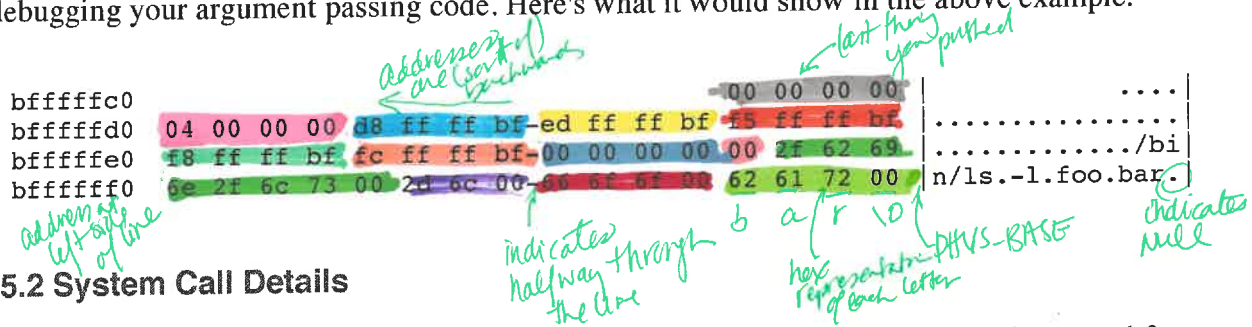
The table below shows the state of the stack and the relevant registers right before the beginning of the user program, assuming PHYS_BASE is 0xc0000000:

Address	Name	Data	Type
0xbffffffc	argv[3][...]	"bar\0"	char[4]
0xbffffff8	argv[2][...]	"foo\0"	char[4]
0xbffffff5	argv[1][...]	"-l\0"	char[3]
0xbfffffed	argv[0][...]	"/bin/ls\0"	char[8]
0xbfffffec	word-align	0	uint8_t
0xbfffffe8	argv[4]	0	char *
0xbfffffe4	argv[3]	0xbffffffc	char *
0xbfffffe0	argv[2]	0xbffffff8	char *
0xbfffffdc	argv[1]	0xbffffff5	char *
0xbfffffd8	argv[0]	0xbfffffed	char *
0xbfffffd4	argv	0xbfffffd8	char **
0xbfffffd0	argv	4	int
0xbfffffcc	return address	0	void (*) ()

In this example, the stack pointer would be initialized to 0xbfffffcc.

As shown above, your code should start the stack at the very top of the user virtual address space, in the page just below virtual address PHYS_BASE (defined in "threads/vaddr.h").

You may find the non-standard hex_dump() function, declared in "<stdio.h>", useful for debugging your argument passing code. Here's what it would show in the above example:



3.5.2 System Call Details

The first project already dealt with one way that the operating system can regain control from a user program: interrupts from timers and I/O devices. These are "external" interrupts, because they are caused by entities outside the CPU (see section A.4.3 External Interrupt Handling).