

Question 2

ltrace

```
ashish@Merseyside:~/Documents/Homework2$ ltrace ./file_io
printf("\nYou'll Never Walk Alone"                                = 24
)
fopen("output.txt", "r")                                         = 0x55b720d9c670
fileno(0x55b720d9c670)                                          = 3
fchmod(3, 0600)                                                  = 0
fopen("output.txt", "w")                                         = 0x55b720d9c8a0
fputc('A', 0x55b720d9c8a0)                                       = 65
fclose(0x55b720d9c8a0)                                          = 0
fopen("output.txt", "a")                                         = 0x55b720d9c8a0
malloc(50)                                                       = 0x55b720d9cad0
printf("\nEnter a string:You'll Never Walk Alone
)                                                                = 16
__isoc99_scanf(0x55b71f0b8caf, 0x55b720d9cad0, 0, 0Enter a string:Tak
)                                                                = 1
fputs("Tak", 0x55b720d9c8a0)                                     = 1
fflush(0x55b720d9c8a0)                                          = 0
fclose(0x55b720d9c8a0)                                          = 0
fopen("output.txt", "r")                                         = 0x55b720d9c8a0
fgetc(0x55b720d9c8a0)                                           = 'A'
printf("\nReceived character: %c", 'A'
)                                                                = 22
fgets("Tak", 8, 0x55b720d9c8a0)                                  = 0x7ffde43c5170
printf("\nReceived string: %s\n", "Tak"Received character: A
Received string: Tak
)                                                                = 22
fclose(0x55b720d9c8a0)                                          = 0
free(0x55b720d9c8a0)                                            = <void>
free(0x55b720d9cad0)                                            = <void>
+++ exited (status 0) +++
```

strace

```
ashish@Merseyside:~/Documents/Homework2$ strace ./file_io
execve("./file_io", [ "./file_io", 0x7ffc5a1bf7d0 /* 56 vars */ ] = 0
brk(NULL) = 0x55e8699de000
access("/etc/ld.so.nohwcap", F_OK) = -1 ENOENT (No such file or directory)
access("/etc/ld.so.preload", R_OK) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
fstat(3, {st_mode=S_IFREG|0644, st_size=86077, ...}) = 0
mmap(NULL, 86077, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f8489a70000
close(3) = 0
access("/etc/ld.so.nohwcap", F_OK) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\3\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\260\34\2\0\0\0\0"... , 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=2030544, ...}) = 0
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f8489a6e000
mmap(NULL, 4131552, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f848946e000
mprotect(0x7f8489655000, 2097152, PROT_NONE) = 0
mmap(0x7f8489855000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1e7000) = 0x7f8489855000
mmap(0x7f848985b000, 15072, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7f848985b000
close(3) = 0
arch_prctl(ARCH_SET_FS, 0x7f8489a6f500) = 0
mprotect(0x7f8489855000, 16384, PROT_READ) = 0
mprotect(0x55e86856a000, 4096, PROT_READ) = 0
mprotect(0x7f8489a86000, 4096, PROT_READ) = 0
munmap(0x7f8489a70000, 86077) = 0
fstat(1, {st_mode=S_IFCHR|0620, st_rdev=makedev(136, 1), ...}) = 0
brk(NULL) = 0x55e8699de000
brk(0x55e8699ff000) = 0x55e8699ff000
write(1, "\n", 1
) = 1
openat(AT_FDCWD, "output.txt", O_RDONLY) = 3
fchmod(3, 0600) = 0
openat(AT_FDCWD, "output.txt", O_WRONLY|O_CREAT|O_TRUNC, 0666) = 4
fstat(4, {st_mode=S_IFREG|0600, st_size=0, ...}) = 0
write(4, "A", 1) = 1
close(4) = 0
openat(AT_FDCWD, "output.txt", O_WRONLY|O_CREAT|O_APPEND, 0666) = 4
lseek(4, 0, SEEK_END) = 1
write(1, "You'll Never Walk Alone\n", 24You'll Never Walk Alone
) = 24
fstat(0, {st_mode=S_IFCHR|0620, st_rdev=makedev(136, 1), ...}) = 0
write(1, "Enter a string:", 15Enter a string:) = 15
read(0, Tak
" Tak\n", 1024) = 4
fstat(4, {st_mode=S_IFREG|0600, st_size=1, ...}) = 0
write(4, "Tak", 3) = 3
```

```
fstat(4, {st_mode=S_IFREG|0600, st_size=1, ...}) = 0
write(4, "Tak", 3) = 3
close(4) = 0
openat(AT_FDCWD, "output.txt", O_RDONLY) = 4
fstat(4, {st_mode=S_IFREG|0600, st_size=4, ...}) = 0
read(4, "ATak", 4096) = 4
write(1, "\n", 1
) = 1
read(4, "", 4096) = 0
write(1, "Received character: A\n", 22Received character: A
) = 22
write(1, "Received string: Tak\n", 21Received string: Tak
) = 21
close(4) = 0
lseek(0, -1, SEEK_CUR) = -1 ESPIPE (Illegal seek)
exit_group(0) = ?
+++ exited with 0 +++
```

perf stat

```
ashish@Merseyside:~/Documents/Homework2$ sudo perf stat ./file_io

You'll Never Walk Alone
Enter a string:Tak

Received character: A
Received string: Tak

Performance counter stats for './file_io':

    0.696231      task-clock (msec)          #    0.000 CPUs utilized
           6      context-switches          #    0.009 M/sec
           0      cpu-migrations            #    0.000 K/sec
          56      page-faults               #    0.080 M/sec
<not supported>  cycles
<not supported>  instructions
<not supported>  branches
<not supported>  branch-misses

    2.015069523 seconds time elapsed
```

Question 3

```
[ 1.659656] ThumbEE CPU extension supported.
[ 1.664138] Registering SWP/SWPB emulation handler
[ 1.669238] SmartReflex Class3 initialized
[ 1.707495] mmc0: host does not support reading read-only switch, assuming write-enable
[ 1.719195] mmc0: new high speed SDHC card at address aaaa
[ 1.727530] mmcblk0: mmc0:aaaa SL16G 14.8 GiB
[ 1.736527]   mmcblk0: p1 p2
[ 1.750071] random: fast init done
[ 1.764857] mmc1: new high speed MMC card at address 0001
[ 1.772842] mmcblk1: mmc1:0001 P1XXXX 3.60 GiB
[ 1.778745] mmcblk1boot0: mmc1:0001 P1XXXX partition 1 2.00 MiB
[ 1.786189] mmcblk1boot1: mmc1:0001 P1XXXX partition 2 2.00 MiB
[ 1.793668] mmcblk1rpmb: mmc1:0001 P1XXXX partition 3 128 KiB
[ 1.804529]   mmcblk1: p1
[ 1.816091] tps65217 0-0024: TPS65217 ID 0xe version 1.2
[ 1.822581] omap_i2c 44e0b000.i2c: bus 0 rev0.11 at 400 kHz
[ 1.832278] omap_i2c 4819c000.i2c: bus 2 rev0.11 at 100 kHz
[ 1.839769] hctosys: unable to open rtc device (rtc0)
[ 1.845060] sr_init: No PMIC hook to init smartreflex
[ 1.850789] sr_init: platform driver register failed for SR
[ 1.908137] EXT4-fs (mmcblk0p2): recovery complete
[ 1.922673] EXT4-fs (mmcblk0p2): mounted filesystem with ordered data mode. Opts: (null)
[ 1.931451] UFS: Mounted root (ext4 filesystem) on device 179:2.
[ 1.940245] devtmpfs: mounted
[ 1.945383] Freeing unused kernel memory: 1024K
[ 2.056859] EXT4-fs (mmcblk0p2): re-mounted. Opts: data=ordered
Starting logging: OK
Initializing random number generator... [ 2.305580] random: dd: uninitialized urandom read (512 bytes read)
done.
Starting network: OK

Welcome to Buildroot, Ashish. YNWA!
buildroot login: root
# cd /
# ls
bin          lib          lost+found  opt          run          tmp
dev          lib32        media       proc         /sbin        usr
etc          linuxrc      mnt         root          sys          var
# cd bin
# ls
arch          duawkap      ln           pidof         sleep
ash           echo         login        ping           stty
busybox       egrep        ls           pipe_progress su
cat           false        lsattr       printenv      sync
chattr        fdflush      mkdir        ps            tar
chgrp         fgrep        mknod        pwd           touch
chmod         getopt       mktemp       resume        true
chown         grep         more         rm            umount
cp            gunzip       mount        rmdir         uname
cpio          gzip         mountpoint  run-parts     usleep
date          hostname     mt           sed           vi
dd            kill         mv           setarch       watch
df            link         netstat     setpriv       zcat
dmesg         linux32      nice        setserial
dnsdomainname linux64      nuke        sh
```

```

# ps - aux
PID    USER      COMMAND
  1 root      init
  2 root      [kthreadd]
  3 root      [kworker/0:0]
  4 root      [kworker/0:0H]
  5 root      [kworker/u2:0]
  6 root      [mm_percpu_wq]
  7 root      [ksoftirqd/0]
  8 root      [rcu_sched]
  9 root      [rcu_bh]
 10 root      [migration/0]
 11 root      [cpuhp/0]
 12 root      [kdevtmpfs]
 13 root      [netns]
 14 root      [kworker/0:1]
 15 root      [oom_reaper]
 16 root      [writeback]
 17 root      [kcompactd0]
 18 root      [crypto]
 19 root      [kblockd]
 20 root      [ata_sff]
 21 root      [watchdogd]
 22 root      [rpciod]
 23 root      [xprtiod]
 24 root      [kauditd]
 25 root      [kswapd0]
 26 root      [nfsiod]
 40 root      [kworker/u2:1]
 42 root      [irq/52-48060000]
 43 root      [kworker/0:2]
 44 root      [kworker/0:3]
 45 root      [ipv6_addrconf]
 46 root      [irq/32-44e0b000]
 47 root      [mmcqd/0]
 48 root      [irq/53-tps65217]
 49 root      [mmcqd/1]
 50 root      [mmcqd/1boot0]
 51 root      [mmcqd/1boot1]
 52 root      [mmcqd/1rpmbl]
 53 root      [irq/33-4819c000]
 54 root      [kworker/0:1H]
 55 root      [jbd2/mmcblk0p2-]
 56 root      [ext4-rsv-conver]
 72 root      /sbin/syslogd -n
 74 root      /sbin/klogd -n
 88 root      -sh
 89 root      [kworker/u2:2]
 93 root      ps - aux

```

Question 4

Execution of the program on BBG

```
[ 1.804773] mmcblk1: p1
[ 1.816313] tps65217 0-0024: TPS65217 ID 0xe version 1.2
[ 1.822795] omap_i2c 44e0b000.i2c: bus 0 rev0.11 at 400 kHz
[ 1.832473] omap_i2c 4819c000.i2c: bus 2 rev0.11 at 100 kHz
[ 1.839976] hctosys: unable to open rtc device (rtc0)
[ 1.845272] sr_init: No PMIC hook to init smartreflex
[ 1.851003] sr_init: platform driver register failed for SR
[ 1.902609] EXT4-fs (mmcblk0p2): recovery complete
[ 1.910746] EXT4-fs (mmcblk0p2): mounted filesystem with ordered data mode. Opts: (null)
[ 1.919593] UFS: Mounted root (ext4 filesystem) on device 179:2.
[ 1.928425] devtmpfs: mounted
[ 1.933580] Freeing unused kernel memory: 1024K
[ 2.045671] EXT4-fs (mmcblk0p2): re-mounted. Opts: data=ordered
Starting logging: OK
Initializing random number generator... [ 2.299677] random: dd: uninitialized urandom read (512 bytes read)
done.
Starting network: OK

Welcome to Buildroot, Ashish. YNWA!
buildroot login: root
# cd /
# ls
bin          lib          media        proc         sys
dev          lib32        mnt          root         tmp
etc          linuxrc      opt          run          usr
file_io      lost+found   output.txt  /sbin        var
# ./file_io

You'll Never Walk Alone
Enter a string:Tak

Received character: A
Received string: Tak
```

ltrace

```
# ltrace ./file_io
dwfl_report_elf file_io00x100000 </file_io> 94: address range overlaps an existing module
Backend initialization failed.
Couldn't load ELF object /lib/ld-uClibc.so.0: Success
__uClibc_main(0x106e8, 1, 0xbe89fe54, 0x104e0 <unfinished ...>
printf("\nYou'll Never Walk Alone"
You'll Never Walk Alone) = 24
fopen("output.txt", "w") = 0x22008
fputc('A', 0x22008) = 65
fclose(0x22008) = 0
fopen("output.txt", "a") = 0x22008
malloc(50) = 0x23058
printf("\nEnter a string:"
Enter a string:) = 16
scanf(0x10924, 0x23058, 1, 1Tak
) = 1
fputs("Tak", 0x22008) = 3
fflush(0x22008) = 0
fclose(0x22008) = 0
fopen("output.txt", "r") = 0x22008
fgetc(0x22008) = 'A'
printf("\nReceived character: %c", 'A'
Received character:) = 22
fgets("Tak", 4, 0x22008) = 0xbe89fcf0
printf("\nReceived string: %s\n", "Tak"A
Received string: Tak
) = 22
fclose(0x22008) = 0
free(0x22008) = <void>
free(0x23058) = <void>
+++ exited (status 0) +++
```

[illegible]

```
# perf stat ./file_io
You'll Never Walk Alone
Enter a string:Tak
Received character: A
Received string: Tak

Performance counter stats for './file_io':

      12.463124      task-clock (msec)      #    0.003 CPUs utilized
           10      context-switches      #    0.802 K/sec
            0      cpu-migrations      #    0.000 K/sec
          31      page-faults      #    0.002 M/sec
     10124740      cycles      #    0.812 GHz
     2953021      instructions      #    0.29  insn per cycle
     332595      branches      #   26.686 M/sec
      80896      branch-misses      #   24.32% of all branches

4.523378000 seconds time elapsed
```

Question 5

1. Bonus: Appropriate error codes returned from the system call for the failure cases
2. Bonus: Used Merge Sort with complexity $O(n \log n)$

Successful Runs:

```
# ./syscalltest
[ 13.390978] Pointer to unsorted array is valid
[ 13.390999] Pointer to sorted array is valid
[ 13.395676]
[ 13.395676] Buffer contents on entering syscall:
[ 13.406762] 890
[ 13.408663] 381
[ 13.410490] 279
[ 13.412313] 991
[ 13.414141] 764
[ 13.415970] 24
[ 13.417757] 432
[ 13.419586] 475
[ 13.421414] 329
[ 13.423238] 51
[ 13.424970] 126
[ 13.426801] 379
[ 13.428679] 62
[ 13.430415] 494
[ 13.432247] 451
[ 13.434071] 203
[ 13.435898] 837
[ 13.437767] 848
[ 13.439594] 808
[ 13.441419] 514
[ 13.443242] 797
[ 13.445070] 873
[ 13.446897] 9
[ 13.448585] 546
[ 13.450413] 993
[ 13.452237] 464
[ 13.454066] 925
[ 13.455893] 526
[ 13.457768] 243
[ 13.459595] 169
[ 13.461425] 211
[ 13.463253] 485
[ 13.465080] 550
[ 13.466908] 843
```



```
13.873815] Buffer contents on completion of the sort:
[ 13.880755] 0
[ 13.882401] 0
[ 13.884050] 4
[ 13.885694] 9
[ 13.887339] 9
[ 13.889032] 17
[ 13.890771] 23
[ 13.892504] 24
[ 13.894241] 37
[ 13.895984] 38
[ 13.897767] 39
[ 13.899509] 47
[ 13.901243] 51
[ 13.902981] 51
[ 13.904716] 62
[ 13.906451] 69
[ 13.908233] 70
[ 13.909968] 70
[ 13.911704] 72
[ 13.913439] 73
[ 13.915176] 76
[ 13.916916] 78
[ 13.918694] 81
[ 13.920435] 83
[ 13.922172] 86
[ 13.923911] 90
[ 13.925642] 90
[ 13.927378] 95
[ 13.929158] 110
[ 13.930988] 113
[ 13.932810] 115
[ 13.934638] 118
[ 13.936464] 125
[ 13.938337] 126
[ 13.940168] 133
[ 13.941996] 135
[ 13.943821] 142
[ 13.945650] 157
[ 13.947475] 158
```

[	14.265061]	848
[	14.266886]	850
[	14.268756]	872
[	14.270591]	873
[	14.272420]	875
[	14.274246]	877
[	14.276073]	886
[	14.277942]	890
[	14.279771]	893
[	14.281599]	897
[	14.283427]	900
[	14.285256]	904
[	14.287087]	909
[	14.288957]	909
[	14.290783]	909
[	14.292610]	912
[	14.294443]	912
[	14.296269]	917
[	14.298139]	920
[	14.299967]	925
[	14.301792]	925
[	14.303619]	929
[	14.305447]	929
[	14.307274]	932
[	14.309149]	943
[	14.310976]	947
[	14.312803]	948
[	14.314629]	956
[	14.316455]	957
[	14.318329]	963
[	14.320154]	963
[	14.321980]	966
[	14.323811]	969
[	14.325636]	970
[	14.327464]	973
[	14.329338]	976
[	14.331166]	978
[	14.332995]	979
[	14.334817]	986
[	14.336644]	991
[	14.338515]	991
[	14.340346]	992
[	14.342173]	993
[	14.343999]	993
[	14.345826]	995

```
Return value: [ 14.448383] Pointer to unsorted array is valid
[ 14.448401] Pointer to sorted array is valid
[ 14.454162]
[ 14.454162] Buffer contents on entering syscall:
[ 14.465149] 520
[ 14.466974] 143
[ 14.468853] 357
[ 14.470681] 168
[ 14.472505] 500
[ 14.474333] 194
[ 14.476164] 78
[ 14.477941] 899
[ 14.479767] 703
[ 14.481594] 955
[ 14.483417] 290
[ 14.485240] 290
[ 14.487064] 384
[ 14.488931] 944
[ 14.490761] 868
[ 14.492589] 155
[ 14.494418] 843
[ 14.496248] 990
[ 14.498117] 799
[ 14.499946] 293
[ 14.501773] 151
[ 14.503599] 532
[ 14.505429] 971
[ 14.507255] 879
[ 14.509119] 322
[ 14.510950] 775
[ 14.512777] 949
[ 14.514603] 990
[ 14.516430] 761
[ 14.518296] 206
[ 14.520125] 214
[ 14.521954] 282
[ 14.523782] 201
```

```
[ 14.932183] Buffer contents on completion of the sort:
[ 14.939121] 0
[ 14.940768] 5
[ 14.942419] 7
[ 14.944064] 7
[ 14.945706] 8
[ 14.947357] 9
[ 14.949042] 38
[ 14.950778] 39
[ 14.952520] 43
[ 14.954256] 49
[ 14.955992] 66
[ 14.957770] 66
[ 14.959507] 69
[ 14.961246] 69
[ 14.962984] 73
[ 14.964718] 73
[ 14.966459] 78
[ 14.968233] 79
[ 14.969969] 83
[ 14.971707] 83
[ 14.973439] 84
[ 14.975179] 89
[ 14.976919] 90
[ 14.978695] 92
[ 14.980433] 95
[ 14.982169] 107
[ 14.983992] 117
[ 14.985821] 119
[ 14.987686] 122
[ 14.989516] 125
[ 14.991347] 127
[ 14.993176] 130
[ 14.995004] 143
[ 14.996830] 149
[ 14.998697] 149
[ 15.000526] 151
```

```

[ 15.330810] 851
[ 15.332636] 854
[ 15.334465] 856
[ 15.336290] 863
[ 15.338155] 863
[ 15.339984] 866
[ 15.341811] 867
[ 15.343643] 868
[ 15.345471] 868
[ 15.347298] 877
[ 15.349164] 878
[ 15.350996] 879
[ 15.352821] 880
[ 15.354651] 895
[ 15.356478] 899
[ 15.358346] 899
[ 15.360173] 907
[ 15.362005] 914
[ 15.363830] 916
[ 15.365652] 919
[ 15.367479] 924
[ 15.369344] 930
[ 15.371171] 935
[ 15.373001] 944
[ 15.374826] 949
[ 15.376652] 955
[ 15.378518] 966
[ 15.380349] 971
[ 15.382177] 972
[ 15.384006] 972
[ 15.385832] 976
[ 15.387697] 978
[ 15.389524] 978
[ 15.391354] 979
[ 15.393181] 985
[ 15.395013] 985
[ 15.396839] 990
[ 15.398704] 990
[ 15.400529] 991
[ 15.402360] 991
[ 15.404190] 992

```

Unsuccessful Runs:

```

Passing a NULL for the destination[ 15.511067] Pointer to unsorted array is valid
on address
Return value: 89
Passing a NULL for[ 15.511086] Null pointer to sorted array
or the source address
Return value: 14
Passing a size 1[ 15.520545] Null pointer to unsorted array
less than 256[ 15.529620] Pointer to unsorted array is valid
[ 15.537387] Pointer to sorted array is valid
Return value: 22# █

```

Time taken for syscall to execute (including all printk commands): $14.345826 - 13.390978 = \mathbf{0.954848}$

Question 6

(The information was collected after every 2 minutes instead of 10 minutes)

Output recorded from the System Calls:

```
# vi crontest.log
Periodic CRON Task
Process ID: 103
User ID: 0
Date-Time: Thu Jan  1 00:02:01 1970
Return value from system call: 0
Periodic CRON Task
Process ID: 105
User ID: 0
Date-Time: Thu Jan  1 00:04:01 1970
Return value from system call: 0
Periodic CRON Task
Process ID: 109
User ID: 0
Date-Time: Thu Jan  1 00:06:01 1970
Return value from system call: 0
Periodic CRON Task
Process ID: 110
User ID: 0
Date-Time: Thu Jan  1 00:08:01 1970
Return value from system call: 0
Periodic CRON Task
Process ID: 111
User ID: 0
Date-Time: Thu Jan  1 00:10:01 1970
Return value from system call: 0
Periodic CRON Task
Process ID: 112
User ID: 0
Date-Time: Thu Jan  1 00:12:01 1970
Return value from system call: 0
Periodic CRON Task
Process ID: 113
User ID: 0
Date-Time: Thu Jan  1 00:14:01 1970
Return value from system call: 0
```