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Lab Group – 4

Lab 7: Code Inspection, Debugging & Static Analysis Tool

Que 1: Program Inspection/Debugging for Long-code from GitHub

We are given the following checklist and we have to find all the possible errors accordingly,

1. Data referencing Errors
2. Data declaration Errors
3. Computation Errors
4. Comparison Errors
5. Control Flow errors
6. Interface errors
7. Input/Output Errors
8. Other Checks

First code is a Node JS file from
https://github.com/Medium/medium-sdk-nodejs/blob/master/test/mediumClient_test.js

The first half of the code is provided here:

```
var medium = require("../");

var nock = require("nock");

var qs = require('querystring');

var should = require("should");

var url = require('url');


describe('MediumClient - constructor', function () {


  it('should throw a MediumError when options are undefined', function (done) {

    (function () { new medium.MediumClient() }).should.throw(medium.MediumError)

    done()

  })


  it('should throw a MediumError when options are empty', function (done) {

    (function () { new medium.MediumClient({}) }).should.throw(medium.MediumError)

    done()

  })
  it('should throw a MediumError when only clientId is provided', function (done) {
    (function () { new medium.MediumClient({clientId: 'xxx'})}).should.throw(medium.MediumError)
    done()
  })

  it('should throw a MediumError when only clientSecret is provided', function (done) {
    (function () { new medium.MediumClient({clientSecret: 'yyy'})}).should.throw(medium.MediumError)
    done()
  })

  it('should succeed when both clientId and clientSecret are provided', function (done) {
    var client = new medium.MediumClient({clientId: 'xxx', clientSecret: 'yyy'})
    done()
  })
})

describe('MediumClient - methods', function () {

  var clientId = 'xxx'
  var clientSecret = 'yyy'
  var client
  beforeEach(function () {
    client = new medium.MediumClient({clientId: clientId, clientSecret: clientSecret})
    nock.disableNetConnect()
  })

  afterEach(function () {
    nock.enableNetConnect();
    delete client
  })

  describe('#setAccessToken', function () {

    it ('sets the access token', function (done) {
      var token = "new token"
      client.setAccessToken(token)
      client._accessToken.should.be.String().and.equal(token)
      done()
    })
  })

  describe('#getAuthorizationUrl', function () {

    it ('returns a valid URL for fetching', function (done) {

      var state = "state"
      var redirectUrl = "https://example.com/callback"
      var scope = [medium.Scope.BASIC_PROFILE, medium.Scope.LIST_PUBLICATIONS,medium.Scope.PUBLISH_POST]
      var authUrlStr = client.getAuthorizationUrl(state, redirectUrl, scope)
      var authUrl = url.parse(authUrlStr, true)

      authUrl.protocol.should.equal('https:')
      authUrl.hostname.should.equal('medium.com')
      authUrl.pathname.should.equal('/m/oauth/authorize')
      authUrl.query.should.deepEqual({
        client_id: clientId,
        scope: scope.join(','),
        response_type: 'code',
        state: state,
        redirect_uri: redirectUrl
      })
      done()
    })
  })

  describe('#exchangeAuthorizationCode', function () {

    it ('makes a request for authorization_code and sets the access token from response', function (done) {
      var code = '12345'
      var grantType = 'authorization_code'
      var redirectUrl = 'https://example.com/callback'
      var requestBody = qs.stringify({
        code: code,
        client_id: clientId,
        client_secret: clientSecret,
        grant_type: grantType,
        redirect_uri: redirectUrl
      })
      // the response might have other parameters. this test only considers the ones called out
      // in the Medium Node SDK documentation
      var accessToken = 'abcdef'
      var refreshToken = 'ghijkl'
      var responseBody = {
        access_token: accessToken,
        refresh_token: refreshToken
      }
      var request = nock('https://api.medium.com/', {
        'Content-Type': 'application/x-www-form-urlencoded'
      })
      .post('/v1/tokens', requestBody)
      .reply(201, responseBody)

      client.exchangeAuthorizationCode(code, redirectUrl, function (err, data) {
        if (err) throw err
        data.access_token.should.equal(accessToken)
        data.refresh_token.should.equal(refreshToken)
        done()
      })
      request.done()
    })
  })

  describe('#exchangeRefreshToken', function () {

    it ('makes a request for authorization_code and sets the access token from response', function (done) {
      var refreshToken = 'fedcba'
      var accessToken = 'lkjihg'
      var requestBody = qs.stringify({
        refresh_token: refreshToken,
        client_id: clientId,
        client_secret: clientSecret,
        grant_type: 'refresh_token'
      })
      // the response might have other parameters. this test only considers the ones called out
      // in the Medium Node SDK documentation
    var responseBody = {
      access_token: accessToken,
      refresh_token: refreshToken
    }
    var request = nock('https://api.medium.com/', {
      'Content-Type': 'application/x-www-form-urlencoded'
    })
    .post('/v1/tokens', requestBody)
    .reply(201, responseBody)

    client.exchangeRefreshToken(refreshToken, function (err, data) {
      if (err) throw err
      data.access_token.should.equal(accessToken)
      data.refresh_token.should.equal(refreshToken)
      done()
    })
    request.done()
  })
})
```

1. **Data Referencing Errors**

- None found.

2. **Data Declaration Errors**

- None found.

3. **Computation Errors**

- None found.

4. **Comparison Errors**

- The assertion client._accessToken.should.be.String().and.equal(token) in the setAccessToken test is checking if _accessToken is a string before ensuring its equality. The order of assertions could lead to an unhandled error if _accessToken is not defined or is not a string.

5. **Control Flow Errors**

- None found.

6. **Interface Errors**

- The method client.setAccessToken(token) is called in the setAccessToken test, but if setAccessToken is not implemented correctly, it could lead to unexpected behavior.

7. **Input/Output Errors**

- The request.done() line in both exchangeAuthorizationCode and exchangeRefreshToken tests is incorrectly placed; it should be called after the request is executed, not directly after the request declaration. This may lead to premature invocation of done() in the context of network requests.

Next half of the code is here:

```
describe('#getUser', function () {
  it ('gets the information from expected URL and returns contents of data envelope', function (done) {
    var response = { data: 'response data' }
    var request = nock('https://api.medium.com')
    .get('/v1/me')
    .reply(200, response)

    client.getUser(function (err, data) {
      if (err) throw err
      data.should.deepEqual(response['data'])
      done()
    })
    request.done()
  })
});

describe('#getPublicationsForUser', function () {
  it ('throws a MediumError when no user ID is provided', function (done) {
    (function () {
      client.getPublicationsForUser({})
    }).should.throw(medium.MediumError)
    done()
  })
  it ('makes a proper GET request to the Medium API and returns contents of data envelope when valid options are provided', function (done) {
    var userId = '123456'
    var response = { data: 'response data' }
    var request = nock('https://api.medium.com/')
    .get('/v1/users/' + userId + '/publications')
    .reply(200, response)

    client.getPublicationsForUser({userId: userId}, function (err, data) {
      if (err) throw err
      data.should.deepEqual(response['data'])
      done()
    })
    request.done()
  })
});

describe('#getContributorsForPublication', function () {
  it ('throws a MediumError when no publication ID is provided', function (done) {
    (function () {
      client.getContributorsForPublication({})
    }).should.throw(medium.MediumError)
    done()
  })
  it ('makes a proper GET request to the Medium API and returns contents of data envelope', function (done) {
    var options = { publicationId: 'abcdef' }
    var response = { data: 'response data' }
    var request = nock('https://api.medium.com/')
    .get('/v1/publications/' + options.publicationId + '/contributors')

    .reply(200, response)


    client.getContributorsForPublication(options, function (err, data) {

      if (err) throw err

      data.should.deepEqual(response['data'])

      done()

    })

    request.done()

  })

});


describe('#createPost', function () {

  it ('makes a proper POST request to the Medium API and returns contents of data envelope', function (done) {

    var options = {

      userId: '123456',

      title: 'new post title',

      content: '<h1>New Post!</h1>',

      contentFormat: 'html',

      tags: ['js', 'unit tests'],

      canonicalUrl: 'http://example.com/new-post',

      publishedAt: '2004-02-12T15:19:21+00:00',

      publishStatus: 'draft',

      license: 'all-rights-reserved'

    }

    var response = { data: 'response data' }

    var request = nock('https://api.medium.com/')

    .post('/v1/users/' + options.userId + '/posts', {

      title: options.title,
      content: options.content,

      contentFormat: options.contentFormat,

      tags: options.tags,

      canonicalUrl: options.canonicalUrl,

      publishedAt: options.publishedAt,

      publishStatus: options.publishStatus,

      license: options.license

    })

    .reply(200, response)


    client.createPost(options, function (err, data) {

      if (err) throw err

      data.should.deepEqual(response['data'])

      done()

    })

    request.done()

  })

});


describe('#createPostInPublication', function () {

  it ('should throw an error when no publication ID is provided', function (done) {

    (function () {

      client.createPostInPublication({})

    }).should.throw(medium.MediumError)

    done()

  })

  it ('makes a proper POST request to the Medium API and returns contents of data envelope',
function (done) {

    var options = {

      publicationId: 'abcdef',
      title: 'new post title',

      content: '<h1>New Post!</h1>',

      contentFormat: 'html',

      tags: ['js', 'unit tests'],

      canonicalUrl: 'http://example.com/new-post',

      publishedAt: '2004-02-12T15:19:21+00:00',

      publishStatus: 'draft',

      license: 'all-rights-reserved'

    }

    var response = { data: 'response data' }

    var request = nock('https://api.medium.com/')

    .post('/v1/publications/' + options.publicationId + '/posts', {

      title: options.title,

      content: options.content,

      contentFormat: options.contentFormat,

      tags: options.tags,

      canonicalUrl: options.canonicalUrl,

      publishedAt: options.publishedAt,

      publishStatus: options.publishStatus,

      license: options.license

    })

    .reply(200, response)


    client.createPostInPublication(options, function (err, data) {

      if (err) throw err

      data.should.deepEqual(response['data'])

      done()

    })

    request.done()
```

```
        })
    });
});
```

Here are the identified errors classified according to your categories in the provided code:

1. Data Referencing Errors
- None found.
2. Data Declaration Errors
- None found.
3. Computation Errors
- None found.
4. Comparison Errors
- In the tests for getUser, getPublicationsForUser, getContributorsForPublication, createPost, and createPostInPublication, the assertion data.should.deepEqual(response['data']) assumes that response['data'] contains the expected output structure. If response.data is not defined correctly or is different in structure, this could lead to a comparison error.
5. Control Flow Errors
- None found.
6. Interface Errors
- None found.
7. Input/Output Errors
- The request.done() call in each test should be executed after the request is processed (after the callback), rather than immediately after the request declaration. This could lead to improper handling of request expectations.

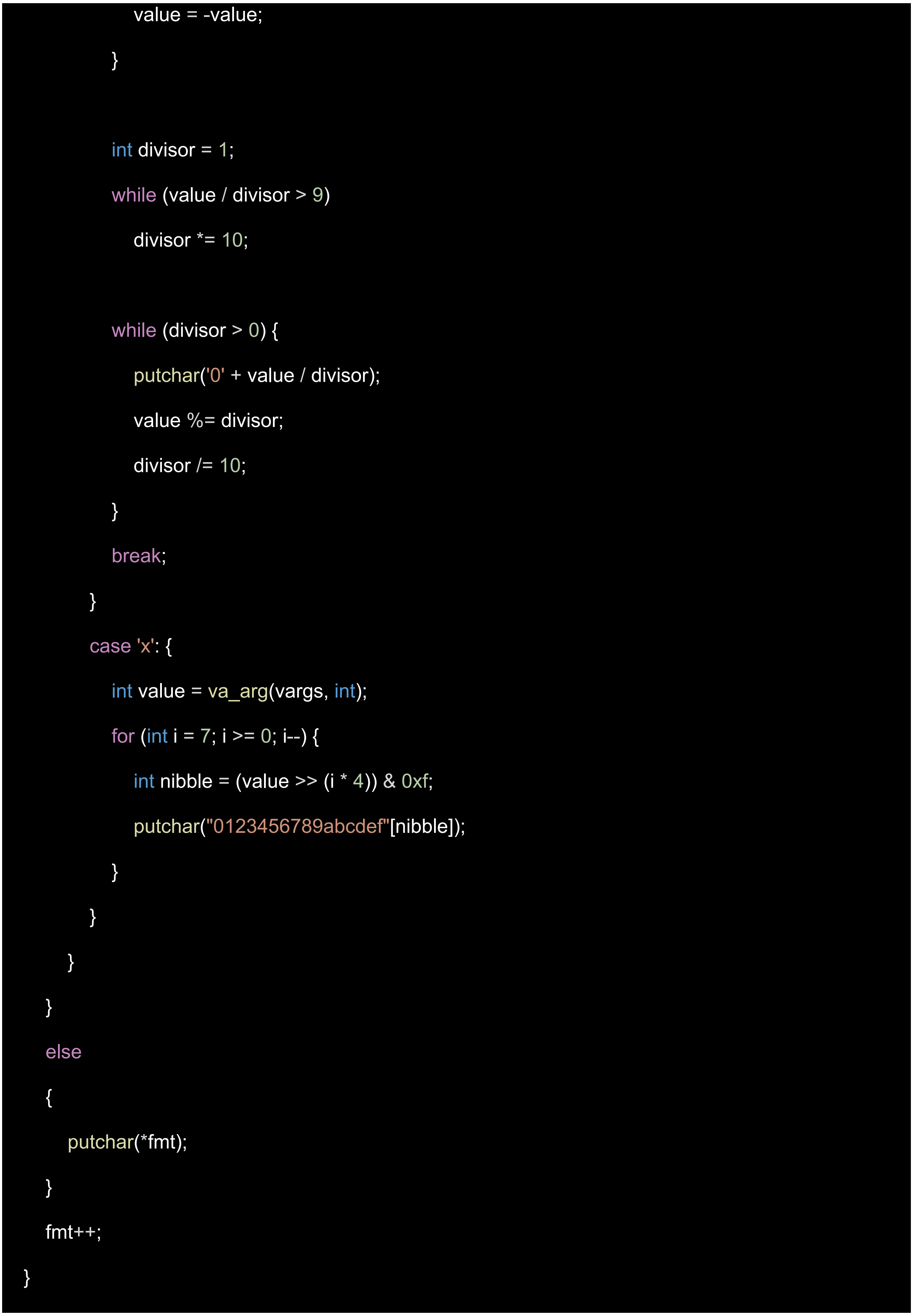
Second code is a sample of a small Operating System
https://github.com/nuta/operating-system-in-1000-lines/tree/main

There are sub parts to it so I placed all of them in random order…

```
#include "common.h"


void *memset(void *buf, char c, size_t n) {
    uint8_t *p = (uint8_t *) buf;
    while (n--)
        *p++ = c;
    return buf;
```

```
}

void *memcpy(void *dst, const void *src, size_t n) {

    uint8_t *d = (uint8_t *) dst;
    const uint8_t *s = (const uint8_t *) src;
    while (n--)
        *d++ = *s++;
    return dst;
}

char *strcpy(char *dst, const char *src) {

    char *d = dst;
    while (*src)
        *d++ = *src++;
    *d = '\0';
    return dst;
}

int strcmp(const char *s1, const char *s2) {

    while (*s1 && *s2) {
        if (*s1 != *s2)
            break;
        s1++;
        s2++;
    }
    return *(unsigned char *)s1 - *(unsigned char *)s2;
```

```
}


void putchar(char ch);


void printf(const char *fmt, ...) {
    va_list vargs;
    va_start(vargs, fmt);
    while (*fmt) {
        if (*fmt == '%') {
            fmt++;
            switch (*fmt) {
                case '\0':
                    putchar('%');
                    goto end;
                case '%':
                    putchar('%');
                    break;
                case 's': {
                    const char *s = va_arg(vargs, const char *);
                    while (*s) {
                        putchar(*s);
                        s++;
                    }
                    break;
                }
                case 'd': {
                    int value = va_arg(vargs, int);
                    if (value < 0) {
                        putchar('-');
```



```
                    value = -value;
                }

                int divisor = 1;
                while (value / divisor > 9)
                    divisor *= 10;

                while (divisor > 0) {
                    putchar('0' + value / divisor);
                    value %= divisor;
                    divisor /= 10;
                }
                break;
            }
            case 'x': {
                int value = va_arg(vargs, int);
                for (int i = 7; i >= 0; i--) {
                    int nibble = (value >> (i * 4)) & 0xf;
                    putchar("0123456789abcdef"[nibble]);
                }
            }
        }
    }
    else
    {
        putchar(*fmt);
    }
    fmt++;
}
```

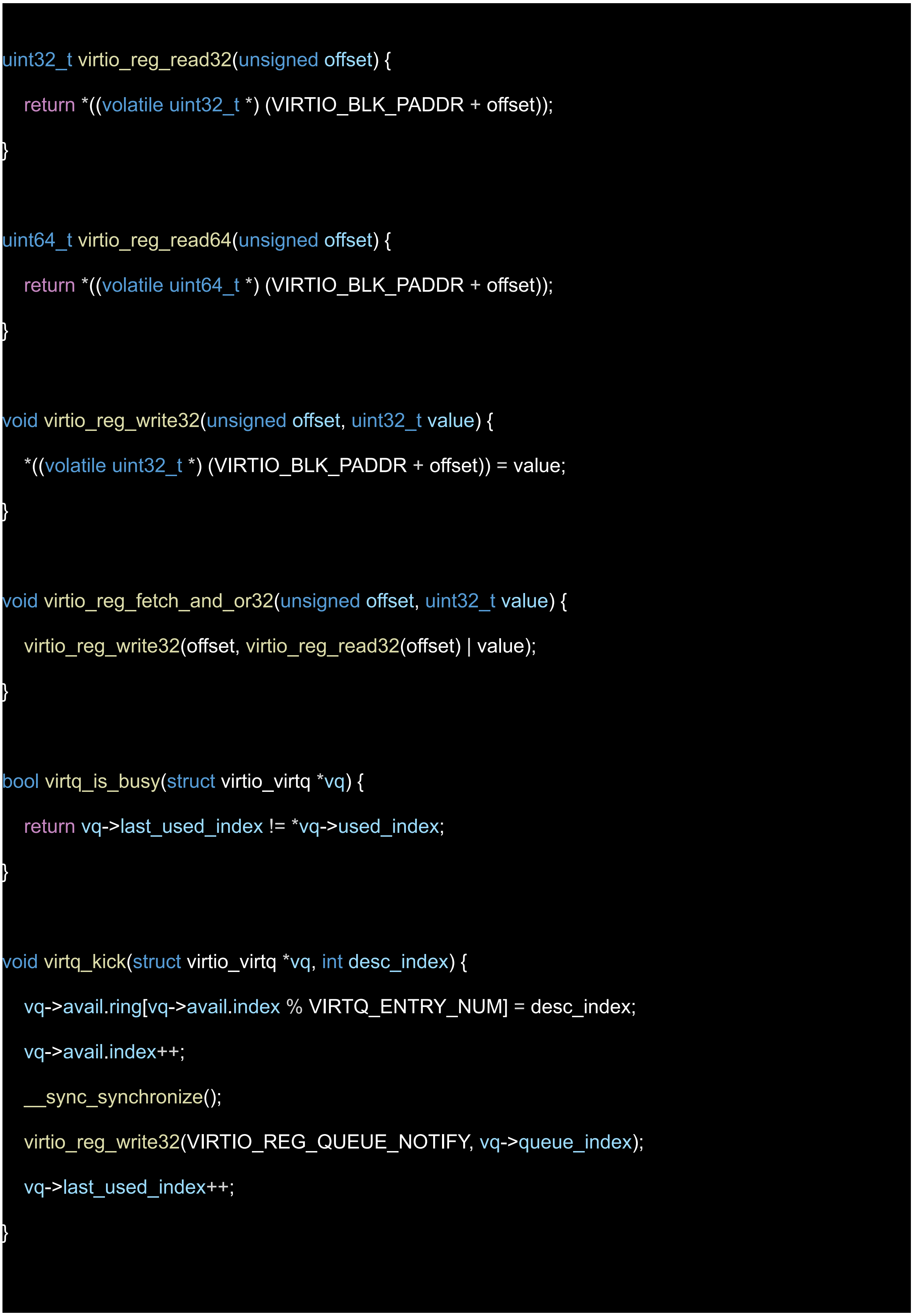
```
end:

   va_end(vargs);

}
```

1. **Data Referencing Errors**
- None found.
2. **Data Declaration Errors**
- In the printf function, the va_list vargs is declared but not properly handled. If va_end(vargs) is called without a corresponding va_start(vargs, fmt), it could lead to undefined behavior, although this isn't directly indicated here since va_start is correctly used before va_end.
3. **Computation Errors**
- None found.
4. **Comparison Errors**
- None found.
5. **Control Flow Errors**
- In the printf function, the goto end; statement inside the switch block can create confusion. Although it is not an error, using goto can lead to less readable code and should be avoided if possible.
6. **Interface Errors**
- The putchar function is declared but not defined in the provided code. This could lead to linker errors if putchar is called without a definition available. - The function printf uses various formats (%d, %x, %s), but there is no error handling for unsupported formats, which could lead to unpredictable behavior if an unsupported format specifier is encountered.
7. **Input/Output Errors**
- In the printf function, there is no check for a null pointer in the const char *s = va_arg(vargs, const char *); line for the string format specifier (%s). If a null pointer is passed, it could lead to dereferencing a null pointer and cause a segmentation fault.

```
#include "kernel.h"

#include "common.h"



extern char __kernel_base[];

extern char __stack_top[];

extern char __bss[], __bss_end[];

extern char __free_ram[], __free_ram_end[];

extern char _binary_shell_bin_start[], _binary_shell_bin_size[];
```

```
struct process procs[PROCS_MAX];

struct process *current_proc;

struct process *idle_proc;


paddr_t alloc_pages(uint32_t n) {

    static paddr_t next_paddr = (paddr_t) __free_ram;

    paddr_t paddr = next_paddr;

    next_paddr += n * PAGE_SIZE;


    if (next_paddr > (paddr_t) __free_ram_end)

        PANIC("out of memory");


    memset((void *) paddr, 0, n * PAGE_SIZE);

    return paddr;

}


void map_page(uint32_t *table1, uint32_t vaddr, paddr_t paddr, uint32_t flags) {

    if (!is_aligned(vaddr, PAGE_SIZE))

        PANIC("unaligned vaddr %x", vaddr);


    if (!is_aligned(paddr, PAGE_SIZE))

        PANIC("unaligned paddr %x", paddr);


    uint32_t vpn1 = (vaddr >> 22) & 0x3ff;

    if ((table1[vpn1] & PAGE_V) == 0) {

        uint32_t pt_paddr = alloc_pages(1);

        table1[vpn1] = ((pt_paddr / PAGE_SIZE) << 10) | PAGE_V;

    }
```

```
  uint32_t vpn0 = (vaddr >> 12) & 0x3ff;
  uint32_t *table0 = (uint32_t *) ((table1[vpn1] >> 10) * PAGE_SIZE);
  table0[vpn0] = ((paddr / PAGE_SIZE) << 10) | flags | PAGE_V;
}

struct sbiret sbi_call(long arg0, long arg1, long arg2, long arg3, long arg4,
                       long arg5, long fid, long eid) {
  register long a0 __asm__("a0") = arg0;
  register long a1 __asm__("a1") = arg1;
  register long a2 __asm__("a2") = arg2;
  register long a3 __asm__("a3") = arg3;
  register long a4 __asm__("a4") = arg4;
  register long a5 __asm__("a5") = arg5;
  register long a6 __asm__("a6") = fid;
  register long a7 __asm__("a7") = eid;

  __asm__ __volatile__("ecall"
                       : "=r"(a0), "=r"(a1)
                       : "r"(a0), "r"(a1), "r"(a2), "r"(a3), "r"(a4), "r"(a5),
                       "r"(a6), "r"(a7)
                       : "memory");
  return (struct sbiret){.error = a0, .value = a1};
}

struct virtio_virtq *blk_request_vq;
struct virtio_blk_req *blk_req;
paddr_t blk_req_paddr;
unsigned blk_capacity;
```



```
uint32_t virtio_reg_read32(unsigned offset) {
    return *((volatile uint32_t *) (VIRTIO_BLK_PADDR + offset));
}

uint64_t virtio_reg_read64(unsigned offset) {
    return *((volatile uint64_t *) (VIRTIO_BLK_PADDR + offset));
}

void virtio_reg_write32(unsigned offset, uint32_t value) {
    *((volatile uint32_t *) (VIRTIO_BLK_PADDR + offset)) = value;
}

void virtio_reg_fetch_and_or32(unsigned offset, uint32_t value) {
    virtio_reg_write32(offset, virtio_reg_read32(offset) | value);
}

bool virtq_is_busy(struct virtio_virtq *vq) {
    return vq->last_used_index != *vq->used_index;
}

void virtq_kick(struct virtio_virtq *vq, int desc_index) {
    vq->avail.ring[vq->avail.index % VIRTQ_ENTRY_NUM] = desc_index;
    vq->avail.index++;
    __sync_synchronize();
    virtio_reg_write32(VIRTIO_REG_QUEUE_NOTIFY, vq->queue_index);
    vq->last_used_index++;
}
```

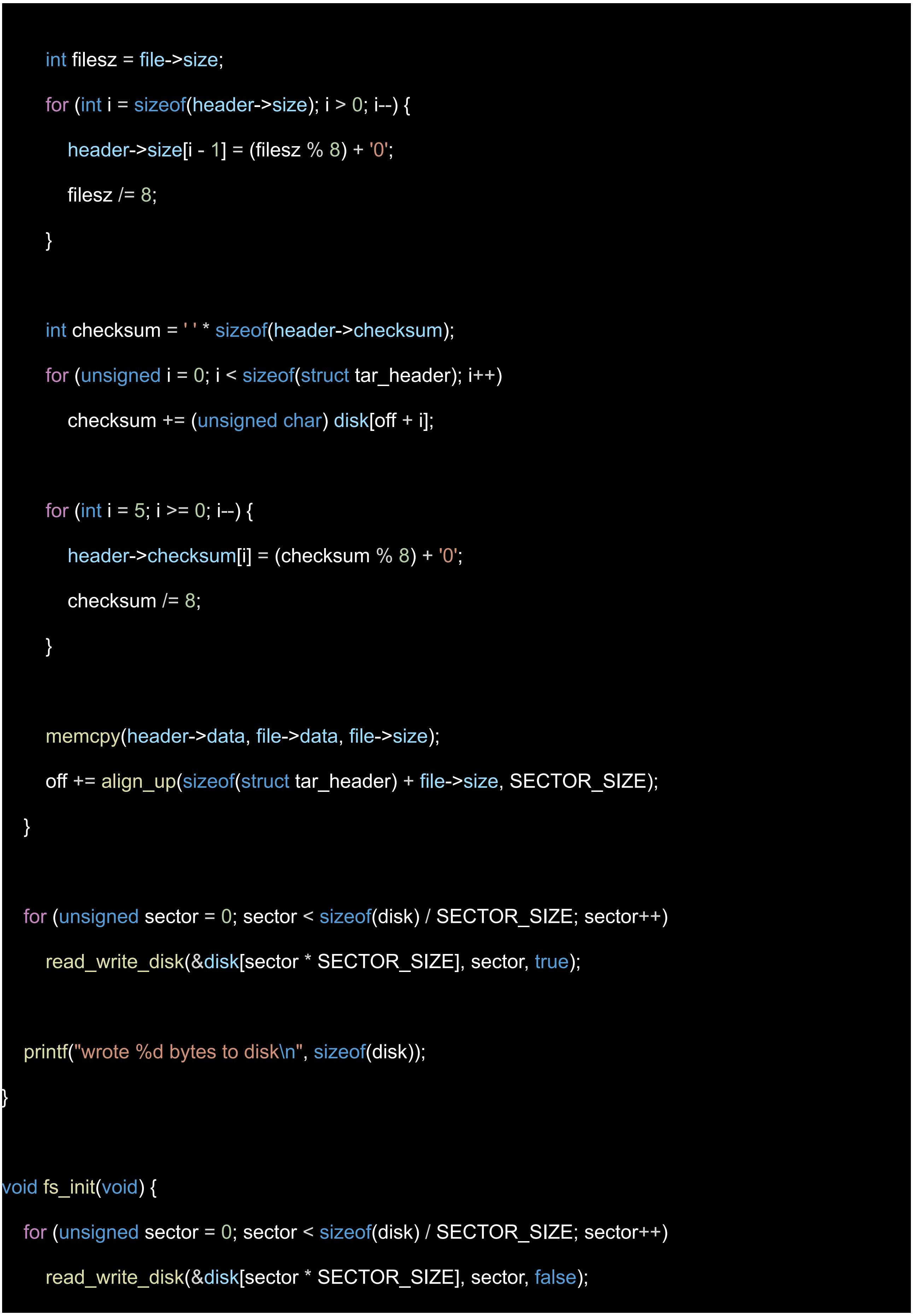
```c
struct virtio_virtq *virtq_init(unsigned index) {
    paddr_t virtq_paddr = alloc_pages(align_up(sizeof(struct virtio_virtq), PAGE_SIZE) / PAGE_SIZE);
    struct virtio_virtq *vq = (struct virtio_virtq *) virtq_paddr;
    vq->queue_index = index;
    vq->used_index = (volatile uint16_t *) &vq->used.index;
    virtio_reg_write32(VIRTIO_REG_QUEUE_SEL, index);
    virtio_reg_write32(VIRTIO_REG_QUEUE_NUM, VIRTQ_ENTRY_NUM);
    virtio_reg_write32(VIRTIO_REG_QUEUE_ALIGN, 0);
    virtio_reg_write32(VIRTIO_REG_QUEUE_PFN, virtq_paddr);
    return vq;
}

void virtio_blk_init(void) {
    if (virtio_reg_read32(VIRTIO_REG_MAGIC) != 0x74726976)
        PANIC("virtio: invalid magic value");
    if (virtio_reg_read32(VIRTIO_REG_VERSION) != 1)
        PANIC("virtio: invalid version");
    if (virtio_reg_read32(VIRTIO_REG_DEVICE_ID) != VIRTIO_DEVICE_BLK)
        PANIC("virtio: invalid device id");

    virtio_reg_write32(VIRTIO_REG_DEVICE_STATUS, 0);
    virtio_reg_fetch_and_or32(VIRTIO_REG_DEVICE_STATUS, VIRTIO_STATUS_ACK);
    virtio_reg_fetch_and_or32(VIRTIO_REG_DEVICE_STATUS, VIRTIO_STATUS_DRIVER);
    virtio_reg_fetch_and_or32(VIRTIO_REG_DEVICE_STATUS, VIRTIO_STATUS_FEAT_OK);
    blk_request_vq = virtq_init(0);
    virtio_reg_write32(VIRTIO_REG_DEVICE_STATUS, VIRTIO_STATUS_DRIVER_OK);

    blk_capacity = virtio_reg_read64(VIRTIO_REG_DEVICE_CONFIG + 0) * SECTOR_SIZE;
    printf("virtio-blk: capacity is %d bytes\n", blk_capacity);
```

```
  blk_req_paddr = alloc_pages(align_up(sizeof(*blk_req), PAGE_SIZE) / PAGE_SIZE);

  blk_req = (struct virtio_blk_req *) blk_req_paddr;

}
```

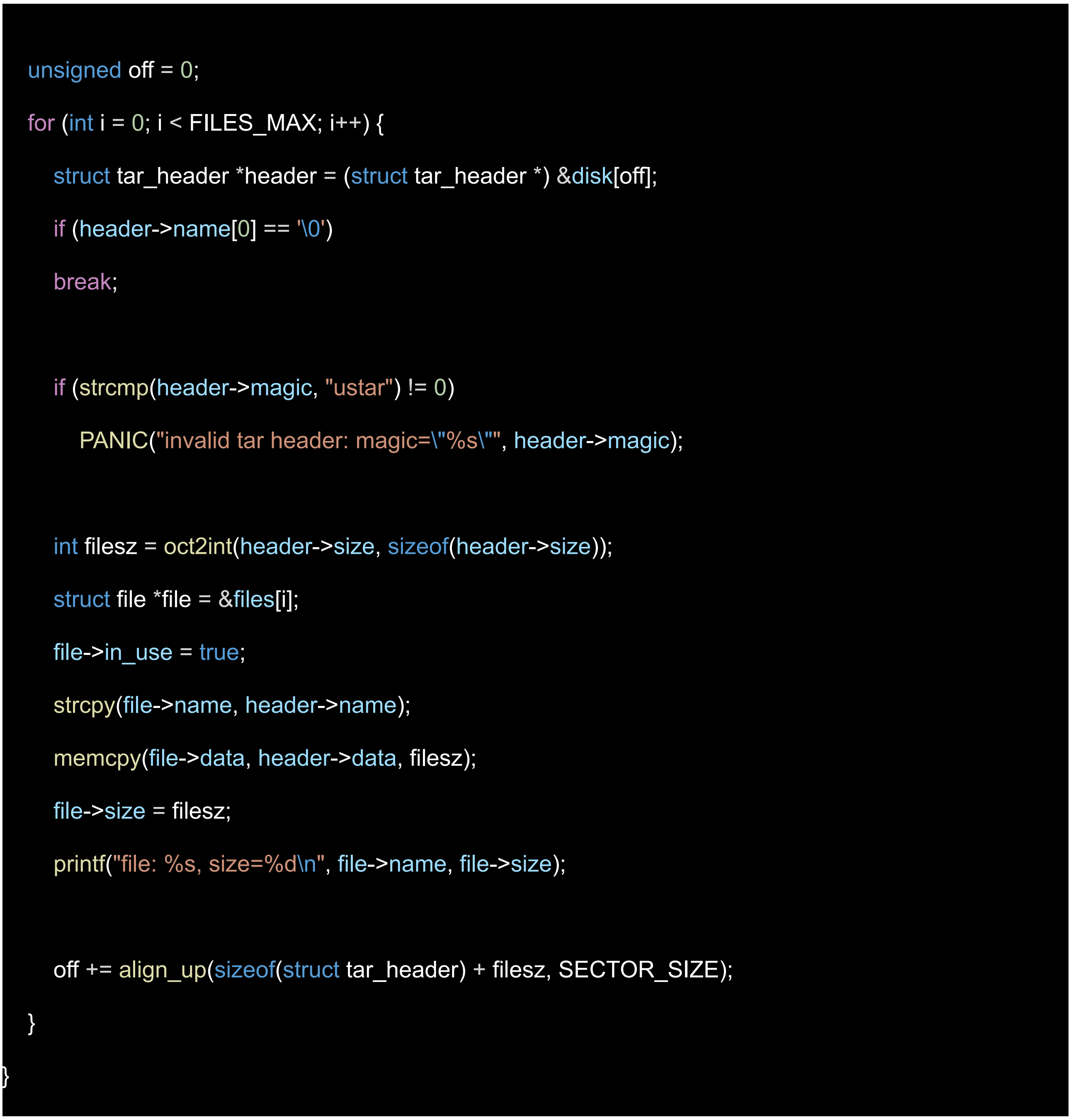
1. **Data Referencing Errors**
- None identified.
2. **Data Declaration Errors**
- None identified.
3. **Computation Errors**
- None identified.
4. **Comparison Errors**
- None identified.
5. **Control Flow Errors**
- No check for successful allocation in virtq_init() after alloc_pages(). This could lead to dereferencing a NULL pointer.
6. **Interface Errors**
- No explicit validation for register offsets in virtio_reg_read32, virtio_reg_read64, and related functions.
7. **Input/Output Errors**
- None identified.

```
void read_write_disk(void *buf, unsigned sector, int is_write) {

  if (sector >= blk_capacity / SECTOR_SIZE) {

    printf("virtio: tried to read/write sector=%d, but capacity is %d\n", sector, blk_capacity /
SECTOR_SIZE);

    return;

  }



  blk_req->sector = sector;

  blk_req->type = is_write ? VIRTIO_BLK_T_OUT : VIRTIO_BLK_T_IN;



  if (is_write)

    memcpy(blk_req->data, buf, SECTOR_SIZE);
  struct virtio_virtq *vq = blk_request_vq;
  vq->descs[0].addr = blk_req_paddr;
  vq->descs[0].len = sizeof(uint32_t) * 2 + sizeof(uint64_t);
  vq->descs[0].flags = VIRTQ_DESC_F_NEXT;
  vq->descs[0].next = 1;

  vq->descs[1].addr = blk_req_paddr + offsetof(struct virtio_blk_req, data);
  vq->descs[1].len = SECTOR_SIZE;
  vq->descs[1].flags = VIRTQ_DESC_F_NEXT | (is_write ? 0 : VIRTQ_DESC_F_WRITE);
  vq->descs[1].next = 2;

  vq->descs[2].addr = blk_req_paddr + offsetof(struct virtio_blk_req, status);
  vq->descs[2].len = sizeof(uint8_t);
  vq->descs[2].flags = VIRTQ_DESC_F_WRITE;

  virtq_kick(vq, 0);
  while (virtq_is_busy(vq))
    ;

  if (blk_req->status != 0) {
    printf("virtio: warn: failed to read/write sector=%d status=%d\n", sector, blk_req->status);
    return;
  }

  if (!is_write)
    memcpy(buf, blk_req->data, SECTOR_SIZE);
}

struct file files[FILES_MAX];
```

```
uint8_t disk[DISK_MAX_SIZE];


int oct2int(char *oct, int len) {
    int dec = 0;
    for (int i = 0; i < len; i++) {
        if (oct[i] < '0' || oct[i] > '7')
            break;

        dec = dec * 8 + (oct[i] - '0');
    }
    return dec;
}


void fs_flush(void) {
    memset(disk, 0, sizeof(disk));
    unsigned off = 0;

    for (int file_i = 0; file_i < FILES_MAX; file_i++) {
        struct file *file = &files[file_i];
        if (!file->in_use)
            continue;

        struct tar_header *header = (struct tar_header *) &disk[off];
        memset(header, 0, sizeof(*header));
        strcpy(header->name, file->name);
        strcpy(header->mode, "000644");
        strcpy(header->magic, "ustar");
        strcpy(header->version, "00");
        header->type = '0';
```



```
        int filesz = file->size;
        for (int i = sizeof(header->size); i > 0; i--) {
            header->size[i - 1] = (filesz % 8) + '0';
            filesz /= 8;
        }

        int checksum = ' ' * sizeof(header->checksum);
        for (unsigned i = 0; i < sizeof(struct tar_header); i++)
            checksum += (unsigned char) disk[off + i];

        for (int i = 5; i >= 0; i--) {
            header->checksum[i] = (checksum % 8) + '0';
            checksum /= 8;
        }

        memcpy(header->data, file->data, file->size);
        off += align_up(sizeof(struct tar_header) + file->size, SECTOR_SIZE);
    }

    for (unsigned sector = 0; sector < sizeof(disk) / SECTOR_SIZE; sector++)
        read_write_disk(&disk[sector * SECTOR_SIZE], sector, true);

    printf("wrote %d bytes to disk\n", sizeof(disk));
}

void fs_init(void) {
    for (unsigned sector = 0; sector < sizeof(disk) / SECTOR_SIZE; sector++)
        read_write_disk(&disk[sector * SECTOR_SIZE], sector, false);
```



```
unsigned off = 0;
for (int i = 0; i < FILES_MAX; i++) {
  struct tar_header *header = (struct tar_header *) &disk[off];
  if (header->name[0] == '\0')
  break;

  if (strcmp(header->magic, "ustar") != 0)
    PANIC("invalid tar header: magic=\"%s\"", header->magic);

  int filesz = oct2int(header->size, sizeof(header->size));
  struct file *file = &files[i];
  file->in_use = true;
  strcpy(file->name, header->name);
  memcpy(file->data, header->data, filesz);
  file->size = filesz;
  printf("file: %s, size=%d\n", file->name, file->size);

  off += align_up(sizeof(struct tar_header) + filesz, SECTOR_SIZE);
}
}
```

1. **Data Referencing Errors**

- The code references blk_req, blk_capacity, blk_request_vq, and blk_req_paddr without showing their definitions. Make sure these variables are properly initialized and referenced.

2. **Data Declaration Errors**

- The variable disk is declared with uint8_t disk[DISK_MAX_SIZE];, but there's no indication of the value assigned to DISK_MAX_SIZE. Ensure it's defined somewhere. - The struct tar_header is referenced without a declaration in the provided code. Ensure it is defined correctly in your project.

3. **Computation Errors**

- The calculation of filesz in fs_flush does not account for the potential overflow when calculating the checksum. Although the tar format specifies a maximum size, it’s a good practice to check sizes to avoid overflow.
- In the oct2int function, if the input oct string has more than three characters (which represent a valid octal digit), the conversion might give unexpected results. Consider adding a limit on len.

4. **Comparison Errors**

- In fs_init, the check if (strcmp(header->magic, "ustar") != 0) is valid, but the code doesn't handle the case where header->magic could be NULL. Consider adding a NULL check before comparison.

5. **Control Flow Errors**

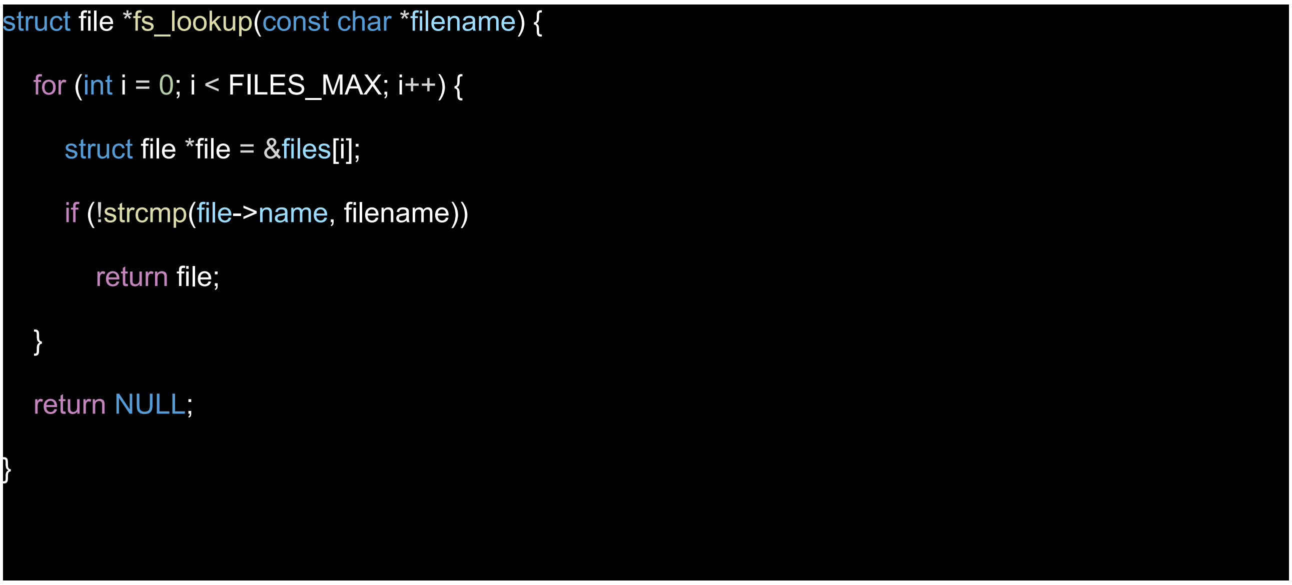
- The read_write_disk function might enter an infinite loop if the disk request is never completed. Ensure that virtq_kick(vq, 0) and virtq_is_busy(vq) are implemented correctly to handle this situation. - The function fs_flush will print that it has written to the disk regardless of whether the write was successful. Consider checking for errors in read_write_disk.

6. **Interface Errors**

- The putchar function must be defined elsewhere, or else there will be linking errors when compiling. - Ensure that align_up is properly defined and that its purpose is clear; it seems to be intended for aligning data sizes, but its implementation is not provided here.

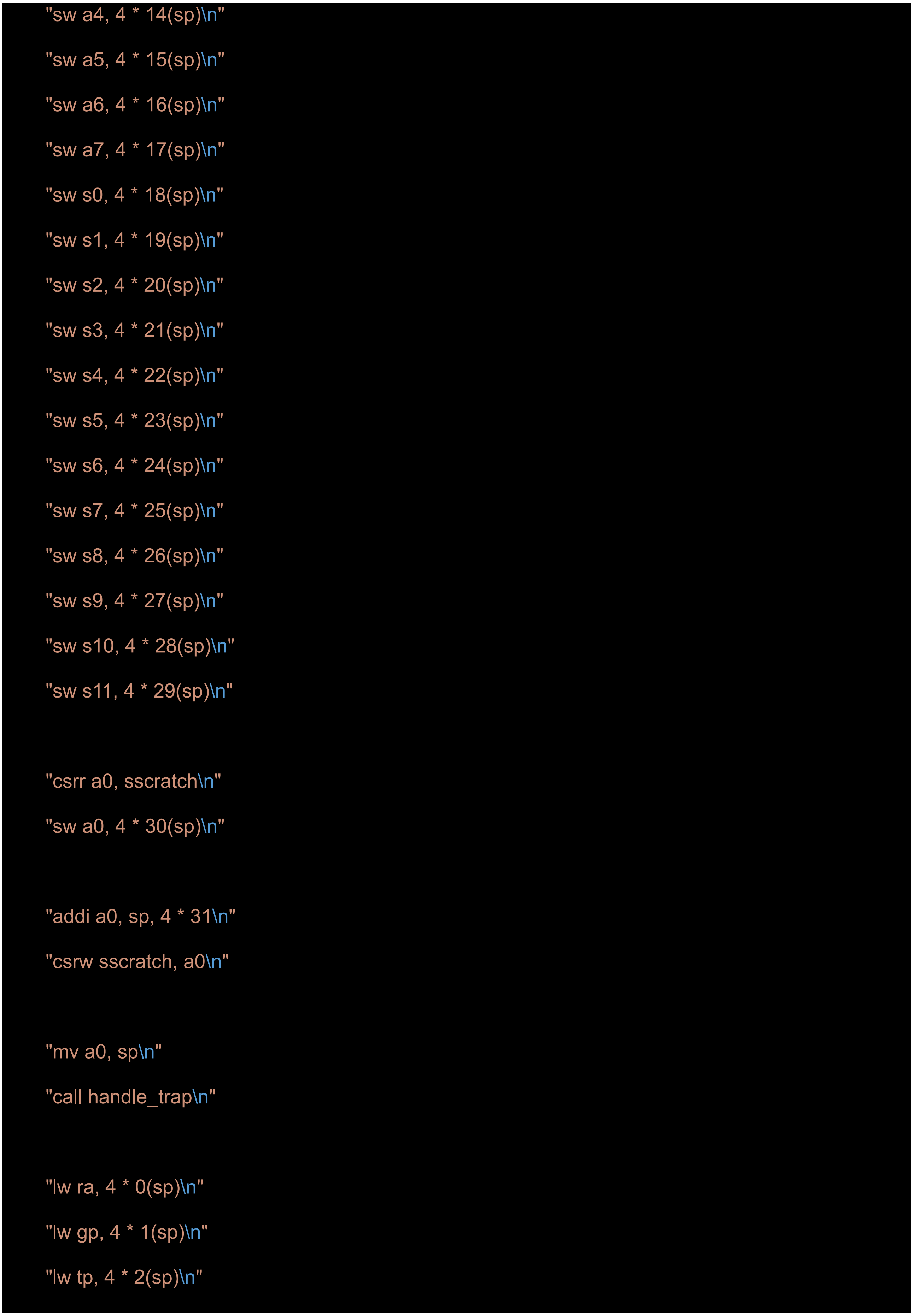
7. **Input/Output Errors**

- In the fs_flush function, when writing to the disk, if read_write_disk fails for any reason (e.g., due to a full disk or hardware failure), the user is not notified. Implement error handling to manage this.
- In the fs_init function, if the data read from the disk doesn’t match the expected format or the file size exceeds DISK_MAX_SIZE, it may cause out-of-bounds memory access when populating the file structures.

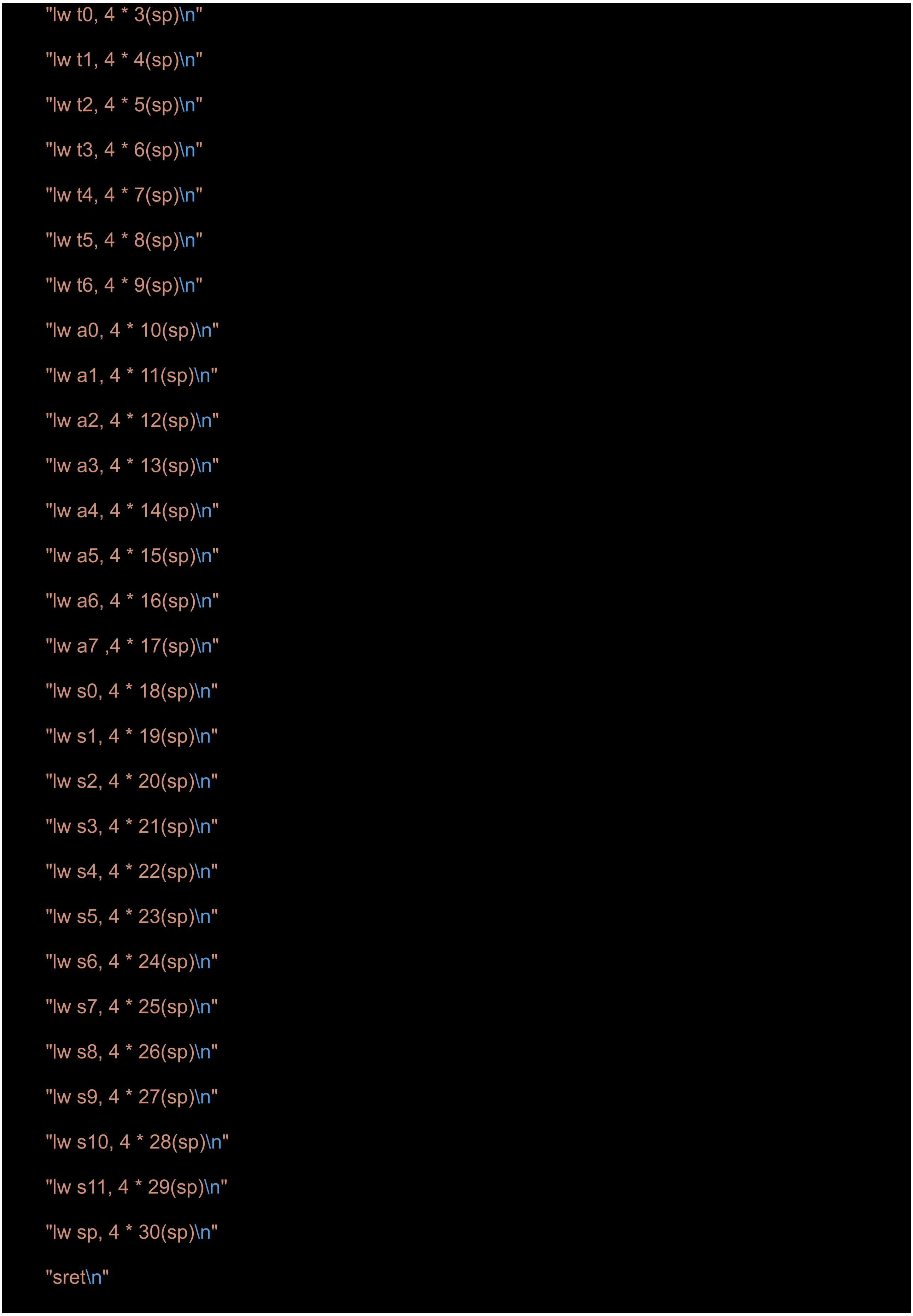


```
struct file *fs_lookup(const char *filename) {

   for (int i = 0; i < FILES_MAX; i++) {

      struct file *file = &files[i];

      if (!strcmp(file->name, filename))

         return file;

   }

   return NULL;

}
```

```
void putchar(char ch) {
    sbi_call(ch, 0, 0, 0, 0, 0, 0, 1 /* Console Putchar */);
}

long getchar(void) {
    struct sbiret ret = sbi_call(0, 0, 0, 0, 0, 0, 0, 2);
    return ret.error;
}

__attribute__((naked))
__attribute__((aligned(4)))
void kernel_entry(void) {
    __asm__ __volatile__(
        "csrrw sp, sscratch, sp\n"
        "addi sp, sp, -4 * 31\n"
        "sw ra, 4 * 0(sp)\n"
        "sw gp, 4 * 1(sp)\n"
        "sw tp, 4 * 2(sp)\n"
        "sw t0, 4 * 3(sp)\n"
        "sw t1, 4 * 4(sp)\n"
        "sw t2, 4 * 5(sp)\n"
        "sw t3, 4 * 6(sp)\n"
        "sw t4, 4 * 7(sp)\n"
        "sw t5, 4 * 8(sp)\n"
        "sw t6, 4 * 9(sp)\n"
        "sw a0, 4 * 10(sp)\n"
        "sw a1, 4 * 11(sp)\n"
        "sw a2, 4 * 12(sp)\n"
        "sw a3, 4 * 13(sp)\n"
```



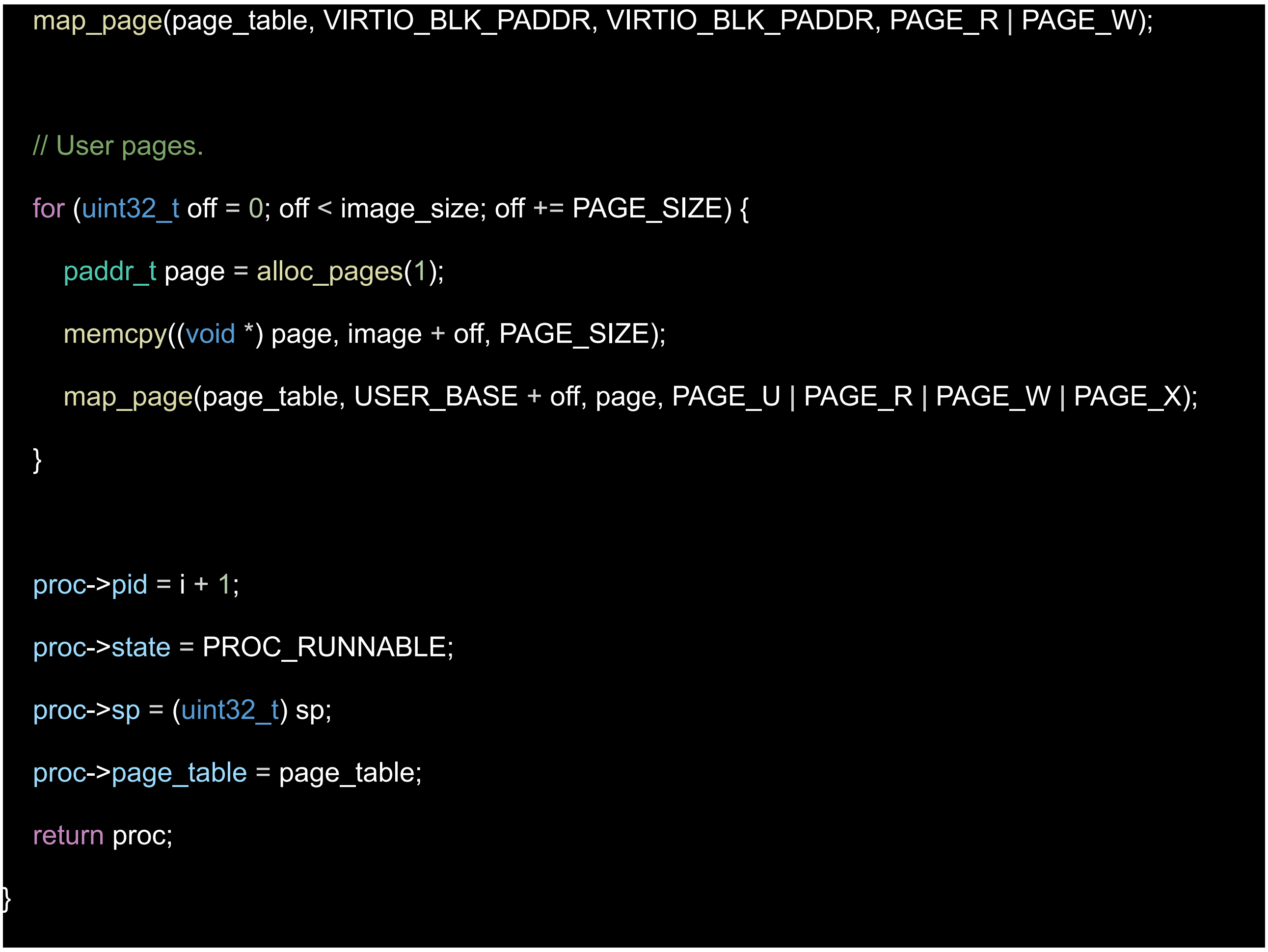
```
    "sw a4, 4 * 14(sp)\n"
    "sw a5, 4 * 15(sp)\n"
    "sw a6, 4 * 16(sp)\n"
    "sw a7, 4 * 17(sp)\n"
    "sw s0, 4 * 18(sp)\n"
    "sw s1, 4 * 19(sp)\n"
    "sw s2, 4 * 20(sp)\n"
    "sw s3, 4 * 21(sp)\n"
    "sw s4, 4 * 22(sp)\n"
    "sw s5, 4 * 23(sp)\n"
    "sw s6, 4 * 24(sp)\n"
    "sw s7, 4 * 25(sp)\n"
    "sw s8, 4 * 26(sp)\n"
    "sw s9, 4 * 27(sp)\n"
    "sw s10, 4 * 28(sp)\n"
    "sw s11, 4 * 29(sp)\n"

    "csrr a0, sscratch\n"
    "sw a0, 4 * 30(sp)\n"

    "addi a0, sp, 4 * 31\n"
    "csrw sscratch, a0\n"

    "mv a0, sp\n"
    "call handle_trap\n"

    "lw ra, 4 * 0(sp)\n"
    "lw gp, 4 * 1(sp)\n"
    "lw tp, 4 * 2(sp)\n"
```



```
"lw t0, 4 * 3(sp)\n"
"lw t1, 4 * 4(sp)\n"
"lw t2, 4 * 5(sp)\n"
"lw t3, 4 * 6(sp)\n"
"lw t4, 4 * 7(sp)\n"
"lw t5, 4 * 8(sp)\n"
"lw t6, 4 * 9(sp)\n"
"lw a0, 4 * 10(sp)\n"
"lw a1, 4 * 11(sp)\n"
"lw a2, 4 * 12(sp)\n"
"lw a3, 4 * 13(sp)\n"
"lw a4, 4 * 14(sp)\n"
"lw a5, 4 * 15(sp)\n"
"lw a6, 4 * 16(sp)\n"
"lw a7 ,4 * 17(sp)\n"
"lw s0, 4 * 18(sp)\n"
"lw s1, 4 * 19(sp)\n"
"lw s2, 4 * 20(sp)\n"
"lw s3, 4 * 21(sp)\n"
"lw s4, 4 * 22(sp)\n"
"lw s5, 4 * 23(sp)\n"
"lw s6, 4 * 24(sp)\n"
"lw s7, 4 * 25(sp)\n"
"lw s8, 4 * 26(sp)\n"
"lw s9, 4 * 27(sp)\n"
"lw s10, 4 * 28(sp)\n"
"lw s11, 4 * 29(sp)\n"
"lw sp, 4 * 30(sp)\n"
"sret\n"
```

```
    );
}

__attribute__((naked)) void user_entry(void) {
    __asm__ __volatile__(
        "csrw sepc, %[sepc]\n"
        "csrw sstatus, %[sstatus]\n"
        "sret\n"
        :
        : [sepc] "r" (USER_BASE),
          [sstatus] "r" (SSTATUS_SPIE | SSTATUS_SUM)
    );
}

__attribute__((naked)) void switch_context(uint32_t *prev_sp,
                                           uint32_t *next_sp) {
    __asm__ __volatile__(
        "addi sp, sp, -13 * 4\n"
        "sw ra, 0 * 4(sp)\n"
        "sw s0, 1 * 4(sp)\n"
        "sw s1, 2 * 4(sp)\n"
        "sw s2, 3 * 4(sp)\n"
        "sw s3, 4 * 4(sp)\n"
        "sw s4, 5 * 4(sp)\n"
        "sw s5, 6 * 4(sp)\n"
        "sw s6, 7 * 4(sp)\n"
        "sw s7, 8 * 4(sp)\n"
        "sw s8, 9 * 4(sp)\n"
        "sw s9, 10 * 4(sp)\n"
        "sw s10, 11 * 4(sp)\n"
        "sw s11, 12 * 4(sp)\n"
        "sw sp, (a0)\n"
        "lw sp, (a1)\n"
        "lw ra, 0 * 4(sp)\n"
        "lw s0, 1 * 4(sp)\n"
        "lw s1, 2 * 4(sp)\n"
        "lw s2, 3 * 4(sp)\n"
        "lw s3, 4 * 4(sp)\n"
        "lw s4, 5 * 4(sp)\n"
        "lw s5, 6 * 4(sp)\n"
        "lw s6, 7 * 4(sp)\n"
        "lw s7, 8 * 4(sp)\n"
        "lw s8, 9 * 4(sp)\n"
        "lw s9, 10 * 4(sp)\n"
        "lw s10, 11 * 4(sp)\n"
        "lw s11, 12 * 4(sp)\n"
        "addi sp, sp, 13 * 4\n"
        "ret\n"
    );
}

struct process *create_process(const void *image, size_t image_size) {
    struct process *proc = NULL;
    int i;
    for (i = 0; i < PROCS_MAX; i++) {
        if (procs[i].state == PROC_UNUSED) {
            proc = &procs[i];
            break;
```

```
  }
}

if (!proc)
  PANIC("no free process slots");

uint32_t *sp = (uint32_t *) &proc->stack[sizeof(proc->stack)];
*--sp = 0; // s11
*--sp = 0; // s10
*--sp = 0; // s9
*--sp = 0; // s8
*--sp = 0; // s7
*--sp = 0; // s6
*--sp = 0; // s5
*--sp = 0; // s4
*--sp = 0; // s3
*--sp = 0; // s2
*--sp = 0; // s1
*--sp = 0; // s0
*--sp = (uint32_t) user_entry; // ra

uint32_t *page_table = (uint32_t *) alloc_pages(1);

// Kernel pages.
for (paddr_t paddr = (paddr_t) __kernel_base;
paddr < (paddr_t) __free_ram_end; paddr += PAGE_SIZE)
map_page(page_table, paddr, paddr, PAGE_R | PAGE_W | PAGE_X);

// virtio-blk
```



```
map_page(page_table, VIRTIO_BLK_PADDR, VIRTIO_BLK_PADDR, PAGE_R | PAGE_W);


// User pages.
for (uint32_t off = 0; off < image_size; off += PAGE_SIZE) {
    paddr_t page = alloc_pages(1);
    memcpy((void *) page, image + off, PAGE_SIZE);
    map_page(page_table, USER_BASE + off, page, PAGE_U | PAGE_R | PAGE_W | PAGE_X);
}


proc->pid = i + 1;
proc->state = PROC_RUNNABLE;
proc->sp = (uint32_t) sp;
proc->page_table = page_table;
return proc;
}
```

1. **Data Referencing Errors**

- Potential Null Pointer Dereference: The fs_lookup function assumes that files are initialized and valid. If files are uninitialized or if FILES_MAX is set to 0, it may lead to undefined behavior.

2. **Data Declaration Errors**

- Missing Struct Definition: The struct file and the files array are referenced but not defined in the provided code. This could lead to compilation errors if they are not declared elsewhere in the program.

3. **Computation Errors**

- None found.

4. **Comparison Errors**

- None found.

5. **Control Flow Errors**

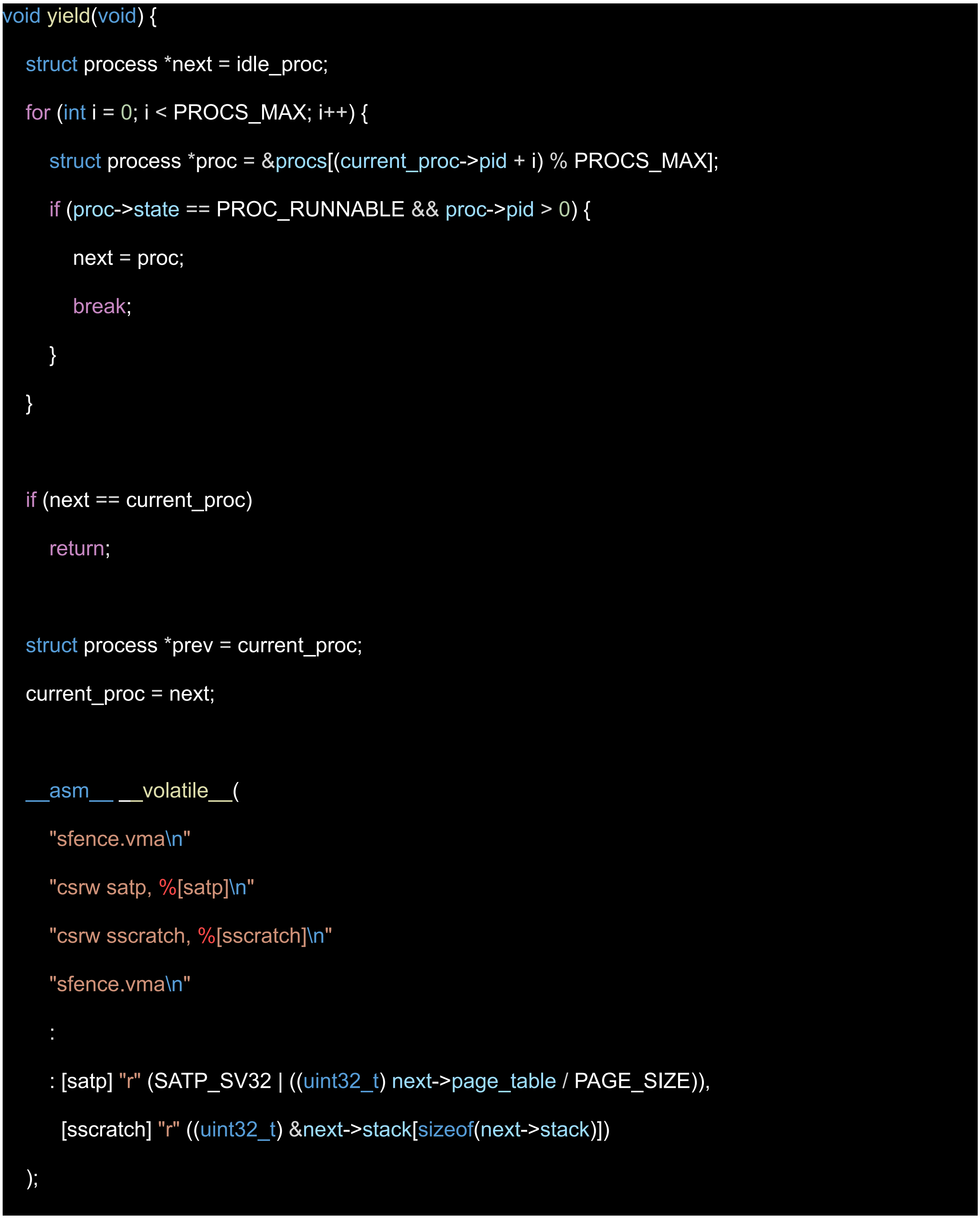
- Unconditional Exit: The PANIC("no free process slots"); call does not handle the case where proc is NULL gracefully, potentially leading to abrupt termination of the program. Instead, it should ideally return or clean up resources.

6. **Interface Errors**

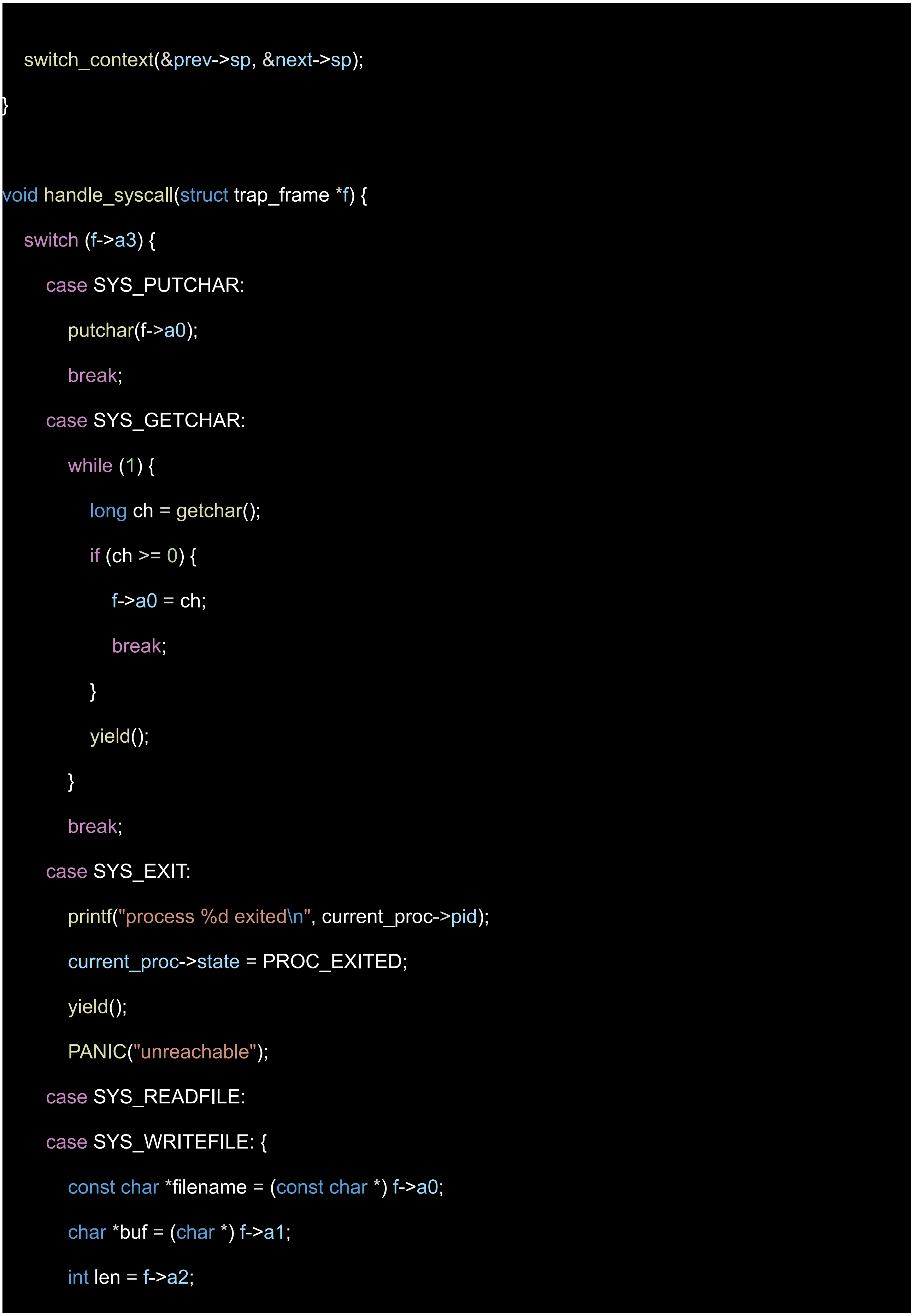
- None found.

7. **Input/Output Errors**

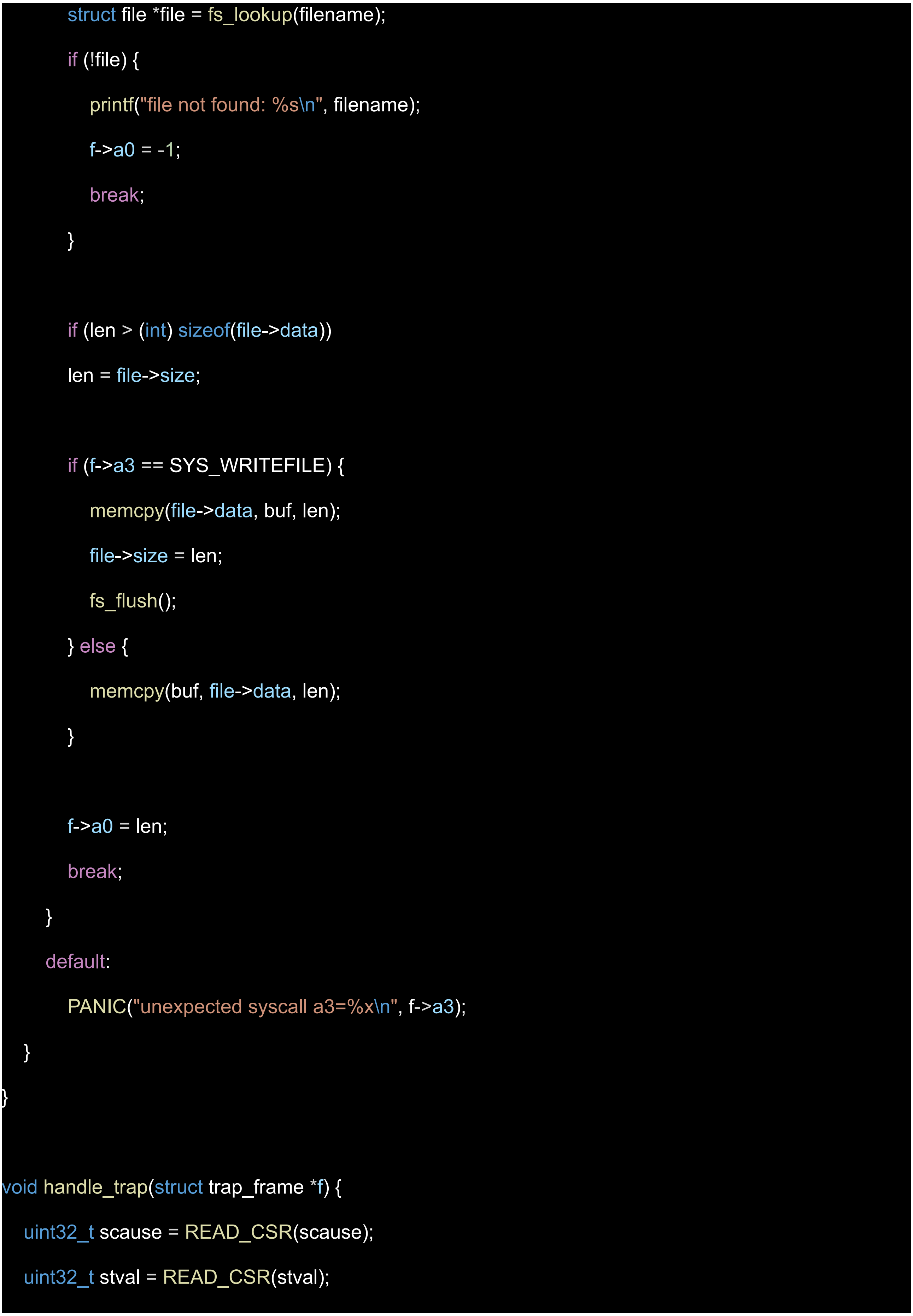
- Buffer Overrun Risk: The loop that initializes the stack (with *--sp = 0;) assumes that the stack has sufficient space. If the size of proc->stack is less than expected, it may result in a stack overflow.



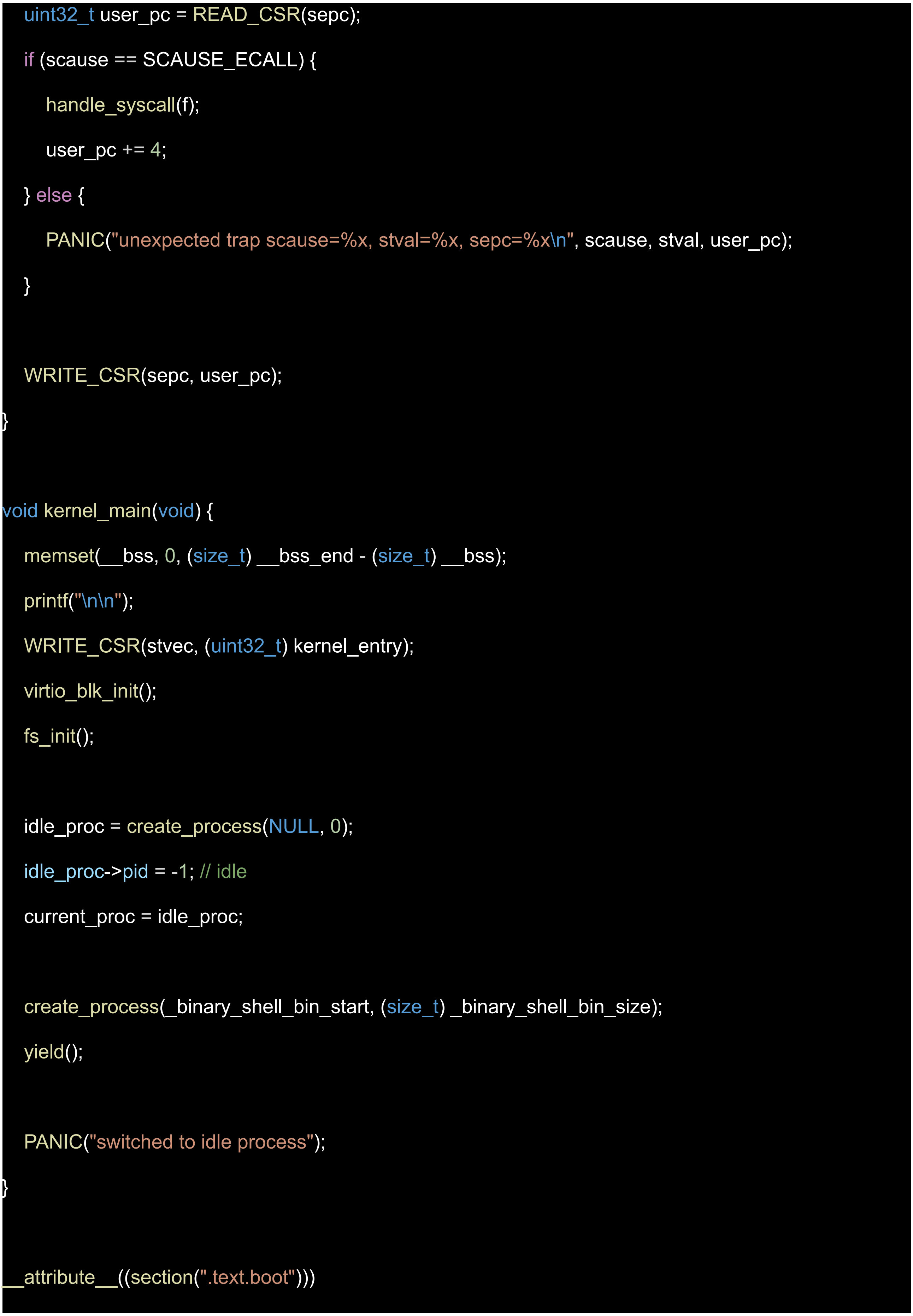
```
void yield(void) {
  struct process *next = idle_proc;
  for (int i = 0; i < PROCS_MAX; i++) {
    struct process *proc = &procs[(current_proc->pid + i) % PROCS_MAX];
    if (proc->state == PROC_RUNNABLE && proc->pid > 0) {
      next = proc;
      break;
    }
  }

  if (next == current_proc)
    return;

  struct process *prev = current_proc;
  current_proc = next;

  __asm__ __volatile__(
    "sfence.vma\n"
    "csrw satp, %[satp]\n"
    "csrw sscratch, %[sscratch]\n"
    "sfence.vma\n"
    :
    : [satp] "r" (SATP_SV32 | ((uint32_t) next->page_table / PAGE_SIZE)),
      [sscratch] "r" ((uint32_t) &next->stack[sizeof(next->stack)])
  );
```



```
    switch_context(&prev->sp, &next->sp);
}

void handle_syscall(struct trap_frame *f) {
    switch (f->a3) {
        case SYS_PUTCHAR:
            putchar(f->a0);
            break;
        case SYS_GETCHAR:
            while (1) {
                long ch = getchar();
                if (ch >= 0) {
                    f->a0 = ch;
                    break;
                }
                yield();
            }
            break;
        case SYS_EXIT:
            printf("process %d exited\n", current_proc->pid);
            current_proc->state = PROC_EXITED;
            yield();
            PANIC("unreachable");
        case SYS_READFILE:
        case SYS_WRITEFILE: {
            const char *filename = (const char *) f->a0;
            char *buf = (char *) f->a1;
            int len = f->a2;
```



```
            struct file *file = fs_lookup(filename);
            if (!file) {
                printf("file not found: %s\n", filename);
                f->a0 = -1;
                break;
            }

            if (len > (int) sizeof(file->data))
            len = file->size;

            if (f->a3 == SYS_WRITEFILE) {
                memcpy(file->data, buf, len);
                file->size = len;
                fs_flush();
            } else {
                memcpy(buf, file->data, len);
            }

            f->a0 = len;
            break;
        }
        default:
            PANIC("unexpected syscall a3=%x\n", f->a3);
    }
}

void handle_trap(struct trap_frame *f) {
    uint32_t scause = READ_CSR(scause);
    uint32_t stval = READ_CSR(stval);
```



```
    uint32_t user_pc = READ_CSR(sepc);
    if (scause == SCAUSE_ECALL) {
        handle_syscall(f);
        user_pc += 4;
    } else {
        PANIC("unexpected trap scause=%x, stval=%x, sepc=%x\n", scause, stval, user_pc);
    }

    WRITE_CSR(sepc, user_pc);
}

void kernel_main(void) {
    memset(__bss, 0, (size_t) __bss_end - (size_t) __bss);
    printf("\n\n");
    WRITE_CSR(stvec, (uint32_t) kernel_entry);
    virtio_blk_init();
    fs_init();

    idle_proc = create_process(NULL, 0);
    idle_proc->pid = -1; // idle
    current_proc = idle_proc;

    create_process(_binary_shell_bin_start, (size_t) _binary_shell_bin_size);
    yield();

    PANIC("switched to idle process");
}

__attribute__((section(".text.boot")))
__attribute__((naked))

void boot(void) {

   __asm__ __volatile__(

      "mv sp, %[stack_top]\n"

      "j kernel_main\n"

      :

      : [stack_top] "r" (__stack_top)

   );

}
```

1. **Data Referencing Errors**

- Potential Null Pointer Dereference: current_proc could be null if no processes have been created or if it has been improperly initialized before yield() is called.

2. **Data Declaration Errors**

- Uninitialized Variables: Variables such as idle_proc and current_proc may be used without proper initialization if create_process fails or if there are no processes.

3. **Computation Errors**

- Improper Memory Access: The calculation of next->page_table / PAGE_SIZE could lead to incorrect values if next->page_table is not properly aligned or initialized.

4. **Comparison Errors**

- Unsigned vs. Signed Comparison: Comparing proc->pid > 0 may cause unintended behavior if proc->pid is an unsigned type.

5. **Control Flow Errors**

- Infinite Loop Risk: The while (1) loop in handle_syscall for SYS_GETCHAR may lead to an infinite loop if getchar() never returns a valid character.

6. **Interface Errors**

- Missing Error Handling for System Calls: Functions like fs_lookup, memcpy, and printf may fail silently without error checking or reporting in certain scenarios.

7. **Input/Output Errors**

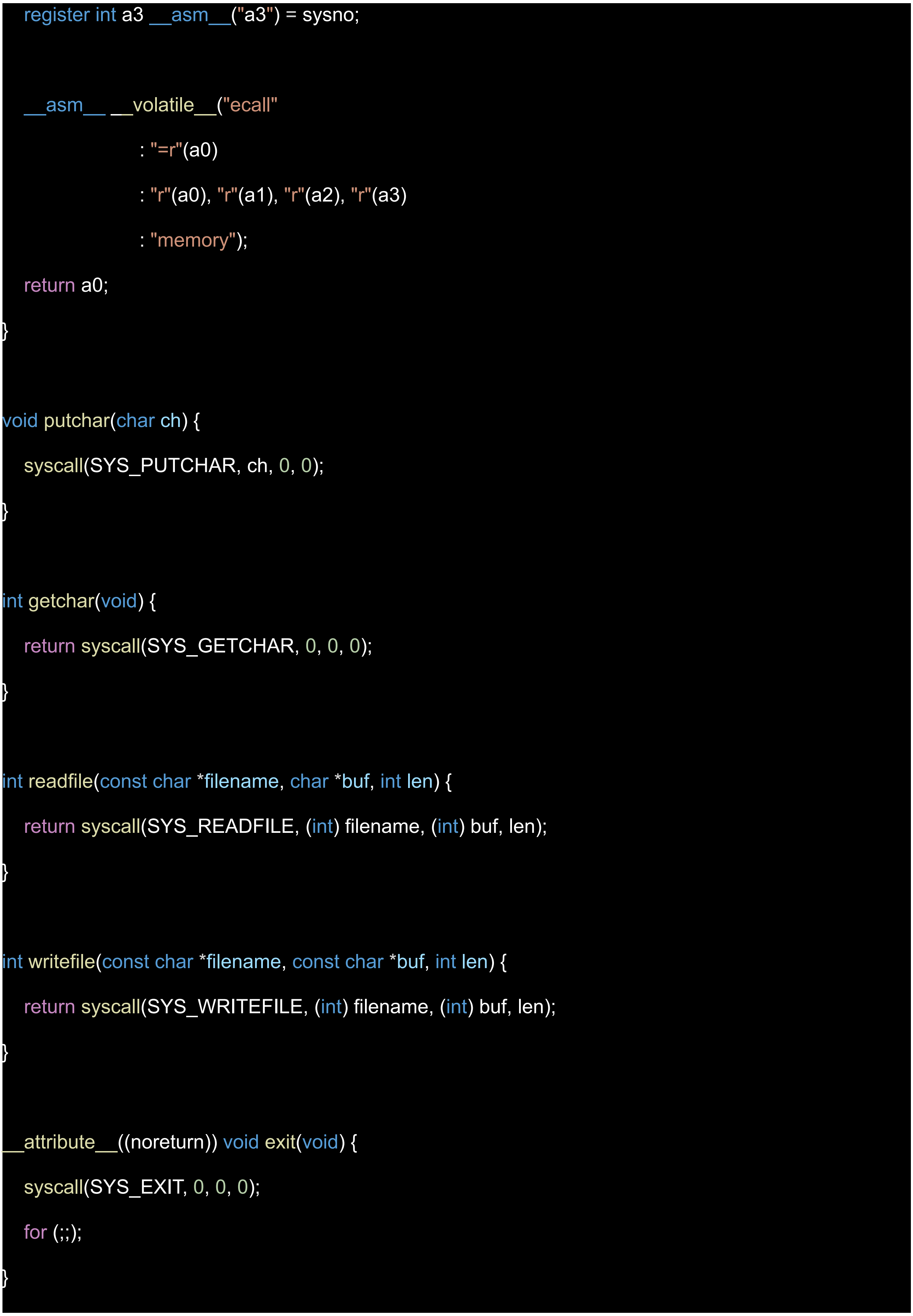
- Data Overwrite Risk: In handle_syscall for SYS_WRITEFILE, if len is not properly validated, it may lead to writing beyond the bounds of file->data.

```
#include "user.h"

void main(void) {

   while (1) {

      prompt:
```

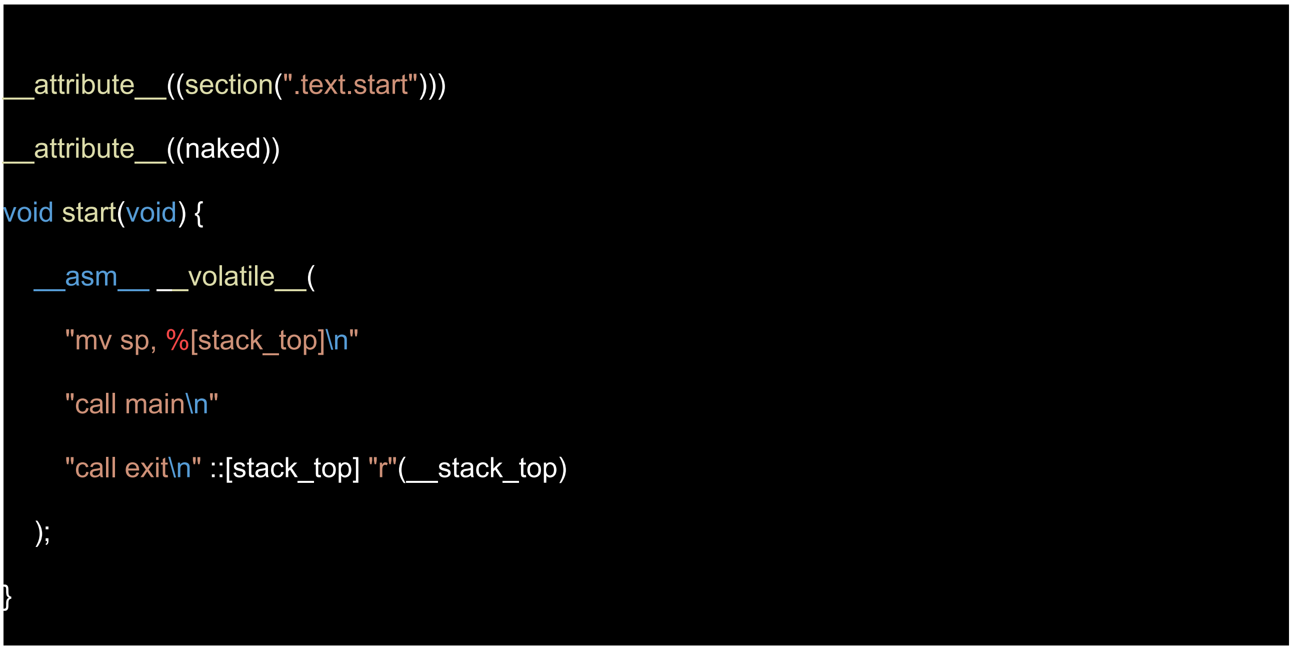
```
printf("> ");
char cmdline[128];
for (int i = 0;; i++) {
    char ch = getchar();
    putchar(ch);
    if (i == sizeof(cmdline) - 1) {
        printf("command line too long\n");
        goto prompt;
    } else if (ch == '\r') {
        printf("\n");
        cmdline[i] = '\0';
        break;
    } else {
        cmdline[i] = ch;
    }
}

if (strcmp(cmdline, "hello") == 0)
    printf("Hello world from shell!\n");
else if (strcmp(cmdline, "exit") == 0)
    exit();
else if (strcmp(cmdline, "readfile") == 0) {
    char buf[128];
    int len = readfile("hello.txt", buf, sizeof(buf));
    buf[len] = '\0';
    printf("%s\n", buf);
}
else if (strcmp(cmdline, "writefile") == 0)
    writefile("hello.txt", "Hello from shell!\n", 19);
    else

      printf("unknown command: %s\n", cmdline);

  }

}
```

1. **Data Referencing Errors**
   - Potential Buffer Overflow: The cmdline buffer is not properly null-terminated if the user inputs more than 127 characters (since one byte is used for the null terminator).
2. **Data Declaration Errors**
   - Uninitialized Variable: The variable buf in the readfile command could be uninitialized if the file reading fails before it is populated.
3. **Computation Errors**
   - Length Calculation: In the readfile command, the length returned by readfile() is used directly without checking if it exceeds the size of buf. If len is larger than 128, this could lead to a buffer overflow when setting buf[len] = '\0';
4. **Comparison Errors**
   - Use of strcmp: If cmdline is not properly null-terminated due to buffer overflow or a missed termination case, the behavior of strcmp can be undefined.
5. **Control Flow Errors**
   - Infinite Loop Risk: The while (1) loop will run indefinitely unless a command that calls exit() is executed. There's no condition to break out of the loop except for exit().
6. **Interface Errors**
   - Missing Error Handling: The return value of readfile is not checked for errors. If the file does not exist or the read fails, it could lead to undefined behavior.
7. **Input/Output Errors**
   - Data Overwrite Risk: In the writefile command, there is no check to ensure that the data being written is less than or equal to the length of the file buffer on the file system.

```
#include "user.h"



extern char __stack_top[];



int syscall(int sysno, int arg0, int arg1, int arg2) {

  register int a0 __asm__("a0") = arg0;

  register int a1 __asm__("a1") = arg1;

  register int a2 __asm__("a2") = arg2;
```



```
    register int a3 __asm__("a3") = sysno;

    __asm__ __volatile__("ecall"
                         : "=r"(a0)
                         : "r"(a0), "r"(a1), "r"(a2), "r"(a3)
                         : "memory");
    return a0;
}

void putchar(char ch) {
    syscall(SYS_PUTCHAR, ch, 0, 0);
}

int getchar(void) {
    return syscall(SYS_GETCHAR, 0, 0, 0);
}

int readfile(const char *filename, char *buf, int len) {
    return syscall(SYS_READFILE, (int) filename, (int) buf, len);
}

int writefile(const char *filename, const char *buf, int len) {
    return syscall(SYS_WRITEFILE, (int) filename, (int) buf, len);
}

__attribute__((noreturn)) void exit(void) {
    syscall(SYS_EXIT, 0, 0, 0);
    for (;;);
}
```



```
__attribute__((section(".text.start")))
__attribute__((naked))
void start(void) {
    __asm__ __volatile__(
        "mv sp, %[stack_top]\n"
        "call main\n"
        "call exit\n" ::[stack_top] "r"(__stack_top)
    );
}
```

1. **Data Referencing Errors**

- Casting Pointers to Integers: The code casts const char *filename and char *buf to int, which can lead to data loss or corruption on architectures where pointers are larger than integers (e.g., 64-bit systems).

2. **Data Declaration Errors**

- Uninitialized Variables: If syscall fails or returns an error value, the variables buf and filename may not be handled properly in readfile and writefile functions, which could lead to unexpected behavior.

3. **Computation Errors**

- Return Value Ignored: In readfile and writefile, the return value from syscall is not checked. If the syscall fails (e.g., file not found), this could lead to undefined behavior when using the data later.

4. **Comparison Errors**

- No apparent comparison errors exist in the provided code.

5. **Control Flow Errors**

- Endless Loop in exit: The for (;;); loop in the exit function will create an infinite loop after the syscall call, which could indicate a lack of proper termination or error handling.

6. **Interface Errors**

- No Error Handling for System Calls: There is no error checking for the return values of syscall in any function. For instance, if a file operation fails, the error is not handled.

7. **Input/Output Errors**

- Invalid Memory Access: If buf in readfile or writefile points to an invalid or unallocated memory address, the code will attempt to read from or write to that memory location, leading to potential crashes or data corruption.

Lab 7: Code Inspection, Debugging & Static Analysis Tool

Que 2: Code Debugging and Program Inspection of the JAVA files.

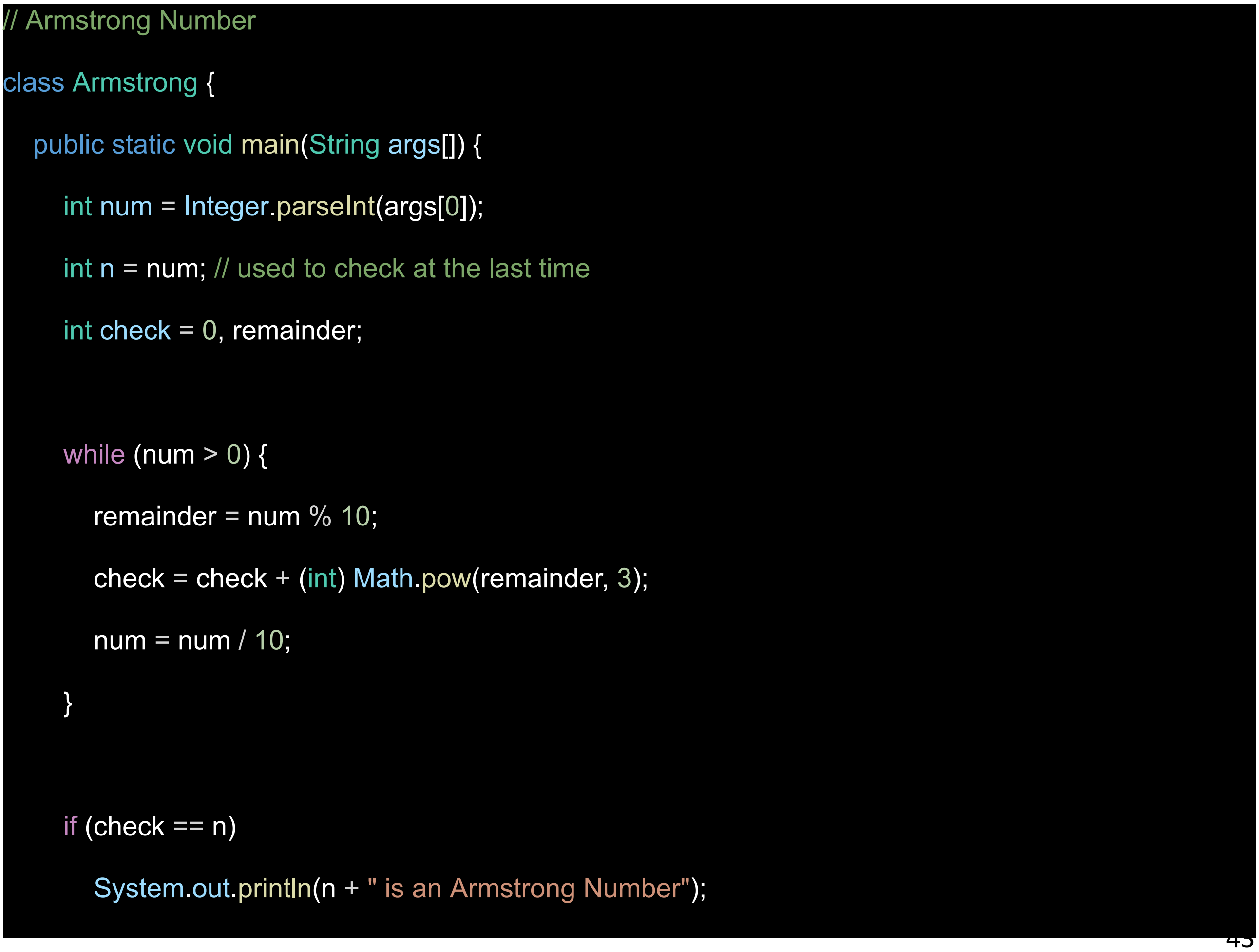
1. Armstrong

A. Program Inspection

1. There is one error in the program, related to the computation of the remainder, and it has been identified and corrected.
2. The most effective category of program inspection for this code is Category C: Computation Errors, as the error pertains to the computation of the remainder, a type of computation error.
3. Program inspection does not identify debugging-related errors. It does not detect issues such as breakpoints or runtime errors like logic errors.
4. The program inspection technique is valuable for identifying and rectifying issues related to code structure and computation errors.

B. Debugging

1. There is one error in the program related to the computation of the remainder, as previously identified.
2. To fix this error, one should set a breakpoint at the point where the remainder is computed to ensure it's calculated correctly. Step through the code to observe the values of variables and expressions during execution. 3. The corrected executable code is as follows:



```
// Armstrong Number

class Armstrong {

    public static void main(String args[]) {

        int num = Integer.parseInt(args[0]);

        int n = num; // used to check at the last time

        int check = 0, remainder;


        while (num > 0) {

            remainder = num % 10;

            check = check + (int) Math.pow(remainder, 3);

            num = num / 10;

        }


        if (check == n)

            System.out.println(n + " is an Armstrong Number");
    else
        System.out.println(n + " is not an Armstrong Number");
  }
}
```

2. GDC and LCM

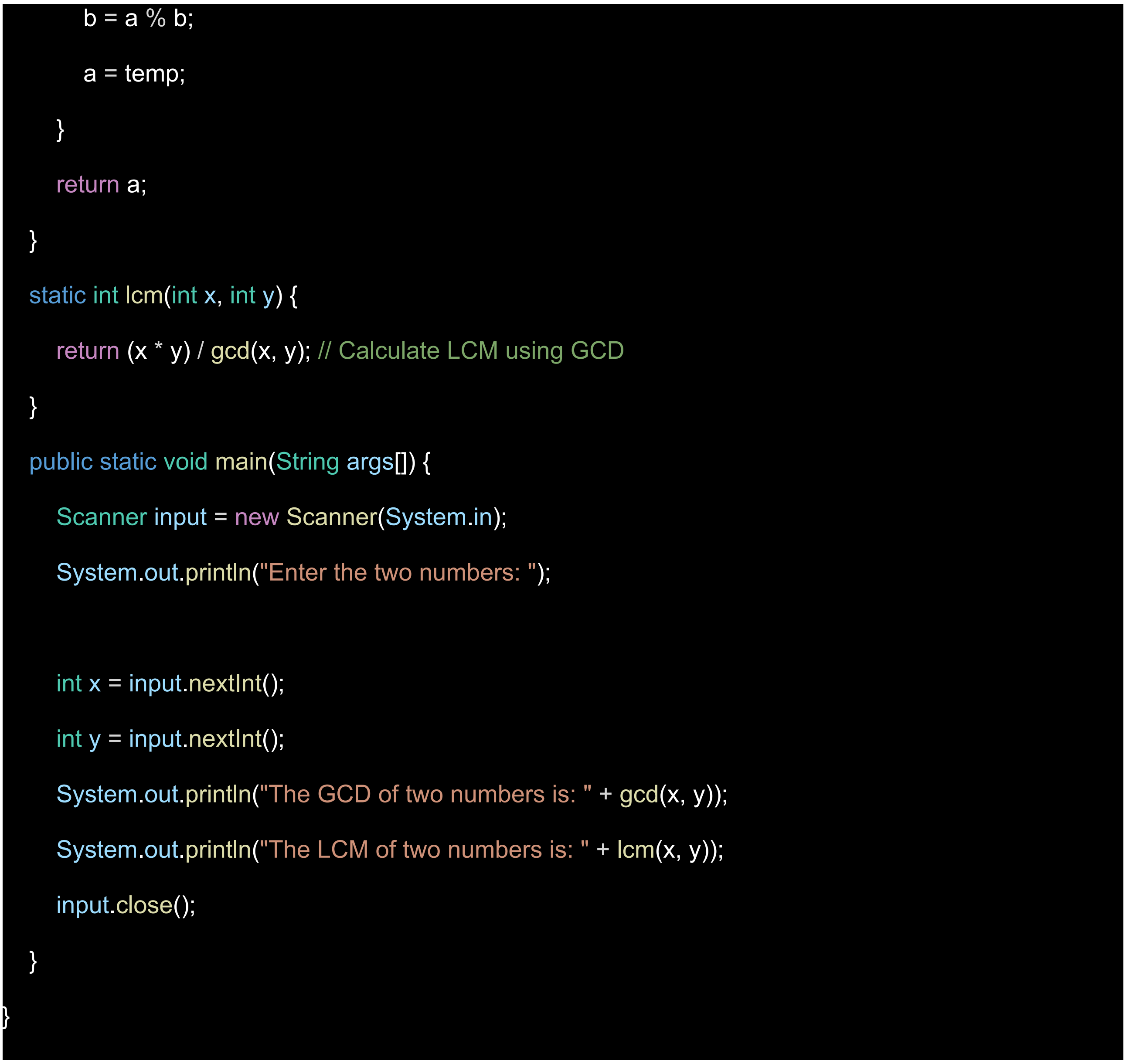
A. Program Inspection

1. There are two errors in the program:
2. Error 1: In the gcd function, the while loop condition should be while(a % b != 0) instead of while(a % b == 0) to calculate the GCD correctly.
3. Error 2: In the lcm function, there is a logic error. The logic used to calculate LCM is incorrect and will result in an infinite loop.
4. For this code, the most effective category of program inspection is Category C: Computation Errors, as it contains computation errors in both the gcd and lcm functions.
5. Program inspection is not able to identify runtime issues or logical errors. It can’t identify errors like infinite loops.
6. The program inspection technique is worth applying to identify and fix computation-related issues.

B. Debugging

1. There are two errors in the program as mentioned above.
2. To fix these errors:
3. For Error 1 in the gcd function, you need one breakpoint at the beginning of the while loop to verify the correct execution of the loop.
4. For Error 2 in the lcm function, you would need to review the logic for calculating LCM, as it’s a logical error.
5. The corrected executable code is as follows:

```
import java.util.Scanner;
public class GCD_LCM {
  static int gcd(int x, int y) {
    int a, b;
    a = (x > y) ? x : y; // a is greater number
    b = (x < y) ? x : y; // b is smaller number

    while (b != 0) { // Fixed the while loop condition
      int temp = b;
```



```
            b = a % b;

            a = temp;

        }

        return a;

    }

    static int lcm(int x, int y) {

        return (x * y) / gcd(x, y); // Calculate LCM using GCD

    }

    public static void main(String args[]) {

        Scanner input = new Scanner(System.in);

        System.out.println("Enter the two numbers: ");


        int x = input.nextInt();

        int y = input.nextInt();

        System.out.println("The GCD of two numbers is: " + gcd(x, y));

        System.out.println("The LCM of two numbers is: " + lcm(x, y));

        input.close();

    }

}
```

3. Knapsack

A. Program Inspection

1. There is one error in the program. It is in the following line: int option1 = opt[n++][w]; The variable n is incremented, which is not intended. It should be: int option1 = opt[n][w];
2. The category of program inspection that would be most effective for this code is Category C: Computation Errors, as the identified error is related to computation within loops.
3. Program inspection is not able to identify runtime errors or logical errors that might arise during program execution.
4. The program inspection technique is worth applying to identify and fix computation-related issues.

B. Debugging

1. There is one error in the program, as identified above.

2. To fix this error, you would need one breakpoint at the line: int option1 = opt[n][w]; to ensure n and w are correctly used without unintended increments.
3. The corrected executable code is as follows:

```
public class Knapsack {
    public static void main(String[] args) {
        int N = Integer.parseInt(args[0]); // number of items
        int W = Integer.parseInt(args[1]); // maximum weight of knapsack

        int[] profit = new int[N + 1];
        int[] weight = new int[N + 1];

        // Generate random instance, items 1..N
        for (int n = 1; n <= N; n++) {
            profit[n] = (int) (Math.random() * 1000);
            weight[n] = (int) (Math.random() * W);
        }
        int[][] opt = new int[N + 1][W + 1];
        boolean[][] sol = new boolean[N + 1][W + 1];

        for (int n = 1; n <= N; n++) {
            for (int w = 1; w <= W; w++) {
                int option1 = opt[n - 1][w]; // Fixed the increment here
                int option2 = Integer.MIN_VALUE;

                if (weight[n] <= w)
                    option2 = profit[n] + opt[n - 1][w - weight[n]];

                opt[n][w] = Math.max(option1, option2);
                sol[n][w] = (option2 > option1);
            }
```

```
      }
      System.out.println("Item" + "\t" + "Profit" + "\t" + "Weight" + "\t" + "Take");


      for (int n = 1; n <= N; n++) {
          System.out.println(n + "\t" + profit[n] + "\t" + weight[n] + "\t" + take[n]);
      }
  }
}
```

4. Magic Number

A. Program Inspection

1. There are two errors in the program:
2. Error 1: In the inner while loop, the condition should be while (sum > 0) instead of while (sum == 0).
3. Error 2: Inside the inner while loop, there are missing semicolons in the lines: s=s*(sum/10); sum=sum%10; They should be corrected as: s = s * (sum / 10); sum = sum % 10;
4. The category of program inspection that would be most effective for this code is Category C: Computation Errors, as it contains computation errors in the while loop.
5. Program inspection is not able to identify runtime issues or logical errors that might arise during program execution.
6. The program inspection technique is worth applying to identify and fix computation-related issues.

B. Debugging

1. There are two errors in the program, as identified above.
2. To fix these errors, you would need one breakpoint at the beginning of the inner while loop to verify the execution of the loop. You can also use breakpoints to check the values of num and s during execution.
3. The corrected executable code is as follows:

```
import java.util.*;


public class MagicNumberCheck {
   public static void main(String args[]) {
      Scanner ob = new Scanner(System.in);
      System.out.println("Enter the number to be checked.");
```

```
        int n = ob.nextInt();
        int sum = 0, num = n;

        while (num > 9) {
            sum = num;
            int s = 0;

            while (sum > 0) { // Fixed the condition here
                s = s * (sum / 10);
                sum = sum % 10; // Fixed the missing semicolon
            }
            num = s;
        }

        if (num == 1) {
            System.out.println(n + " is a Magic Number.");
        } else {
            System.out.println(n + " is not a Magic Number.");
        }
    }
}
```

5. Merge Sort

A. Program Inspection

1. There are several errors in the program:
2. Error 1: In the mergeSort method, the lines int[] left = leftHalf(array+1); and int[] right = rightHalf(array-1); should be corrected. It seems like an attempt to split the array, but it's not done correctly.
3. Error 2: The leftHalf and rightHalf methods are incorrect. They should return the correct halves of the array.

4. Error 3: The merge method should have left and right arrays as inputs, not left++ and right--.
5. The category of program inspection that would be most effective for this code is Category C: Computation Errors, as there are computation-related issues in the code.
6. Program inspection cannot identify runtime issues or logical errors that might arise during program execution.
7. The program inspection technique is worth applying to identify and fix computation-related issues.

B. Debugging

1. There are multiple errors in the program, as identified above.
2. To fix these errors, you would need to set breakpoints to examine the values of left, right and array during execution. You can also use breakpoints to check the values of i1 and i2 inside the merge method.
3. The corrected executable code is as follows:

```java
import java.util.*;
public class MergeSort {
  public static void main(String[] args) {
    int[] list = {14, 32, 67, 76, 23, 41, 58, 85};
    System.out.println("before: " + Arrays.toString(list));

    mergeSort(list);
    System.out.println("after: " + Arrays.toString(list));
  }
  public static void mergeSort(int[] array) {
    if (array.length > 1) {
      int[] left = leftHalf(array);
      int[] right = rightHalf(array);

      mergeSort(left);
      mergeSort(right);
      merge(array, left, right);
    }
  }
```

```
public static int[] leftHalf(int[] array) {
    int size1 = array.length / 2;
    int[] left = new int[size1];

    for (int i = 0; i < size1; i++) {
        left[i] = array[i];
    }
    return left;
}

public static int[] rightHalf(int[] array) {
    int size1 = array.length / 2;
    int size2 = array.length - size1;
    int[] right = new int[size2];

    for (int i = 0; i < size2; i++) {
        right[i] = array[i + size1];
    }
    return right;
}
public static void merge(int[] result, int[] left, int[] right) {
    int i1 = 0;
    int i2 = 0;

    for (int i = 0; i < result.length; i++) {
        if (i2 >= right.length || (i1 < left.length && left[i1] <= right[i2])) {
            result[i] = left[i1];
            i1++;
        } else {
                result[i] = right[i2];

                i2++;

            }

        }

    }

}
```

6. Multiply Matrices

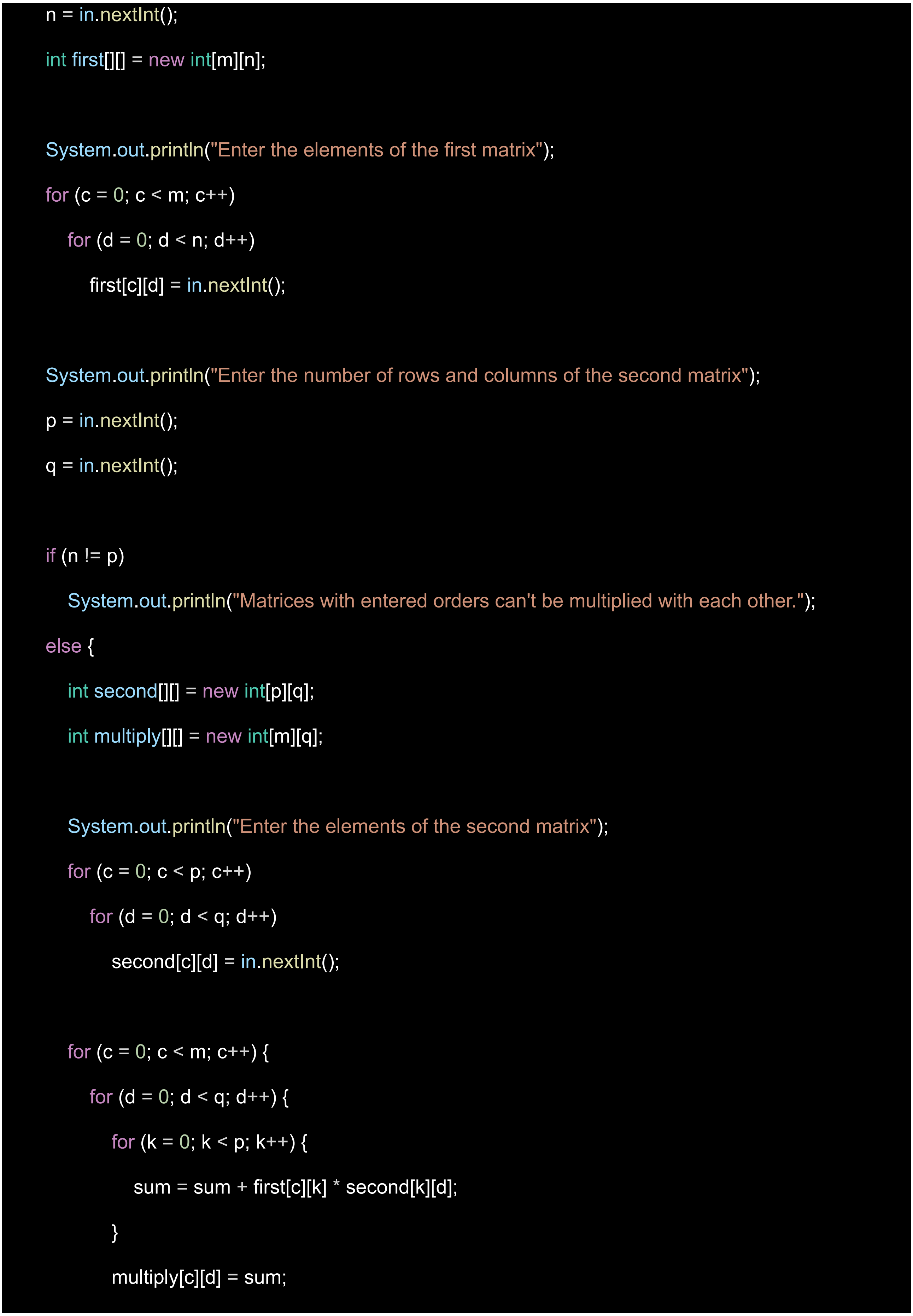
A. Program Inspection

1. There are several errors in the program:
2. Error 1: In the nested loops for matrix multiplication, the loop indices should start from 0, not -1.
3. Error 2: The error message when the matrix dimensions are incompatible should print ”Matrices with entered orders can’t be multiplied with each other,” not ”Matrices with entered orders can’t be multiplied with each other.”
4. The category of program inspection that would be most effective for this code is Category C: Computation Errors, as there are computation-related issues in the code.
5. Program inspection cannot identify runtime issues or logical errors that might arise during program execution.
6. The program inspection technique is worth applying to identify and fix computation-related issues.

B. Debugging

1. There are multiple errors in the program, as identified above.
2. To fix these errors, you would need to set breakpoints to examine the values of c, d, k, and sum during execution. You should pay particular attention to the nested loops where the matrix multiplication occurs.
3. The corrected executable code is as follows:

```
import java.util.Scanner;

class MatrixMultiplication {

    public static void main(String args[]) {

        int m, n, p, q, sum = 0, c, d, k;

        Scanner in = new Scanner(System.in);


        System.out.println("Enter the number of rows and columns of the first matrix");

        m = in.nextInt();
```



```
n = in.nextInt();
int first[][] = new int[m][n];

System.out.println("Enter the elements of the first matrix");
for (c = 0; c < m; c++)
    for (d = 0; d < n; d++)
        first[c][d] = in.nextInt();

System.out.println("Enter the number of rows and columns of the second matrix");
p = in.nextInt();
q = in.nextInt();

if (n != p)
    System.out.println("Matrices with entered orders can't be multiplied with each other.");
else {
    int second[][] = new int[p][q];
    int multiply[][] = new int[m][q];

    System.out.println("Enter the elements of the second matrix");
    for (c = 0; c < p; c++)
        for (d = 0; d < q; d++)
            second[c][d] = in.nextInt();

    for (c = 0; c < m; c++) {
        for (d = 0; d < q; d++) {
            for (k = 0; k < p; k++) {
                sum = sum + first[c][k] * second[k][d];
            }
            multiply[c][d] = sum;
```

```
          sum = 0;

        }

      }


      System.out.println("Product of entered matrices:-");


      for (c = 0; c < m; c++) {

        for (d = 0; d < q; d++) {

          System.out.print(multiply[c][d] + "\t");

          System.out.print("\n");

        }

      }

    }

  }

}
```

7. Quadratic Probing

A. Program Inspection

1. There are multiple errors in the program:
2. Error 1: The insert method has a typo in the line i + = (i + h / h–)
3. Error 2: In the remove method, there is a logic error in the loop to rehash keys. It should be i = (i + h * h++)
4. Error 3: In the get method, there is a logic error in the loop to find the key. It should be i = (i + h * h++)
5. The category of program inspection that would be most effective for this code is Category A: Syntax Errors and Category B: Semantic Errors, as there are both syntax errors and semantic issues in the code.
6. The program inspection technique is worth applying to identify and fix these errors, but it may not identify logical errors that affect the program’s behaviour.

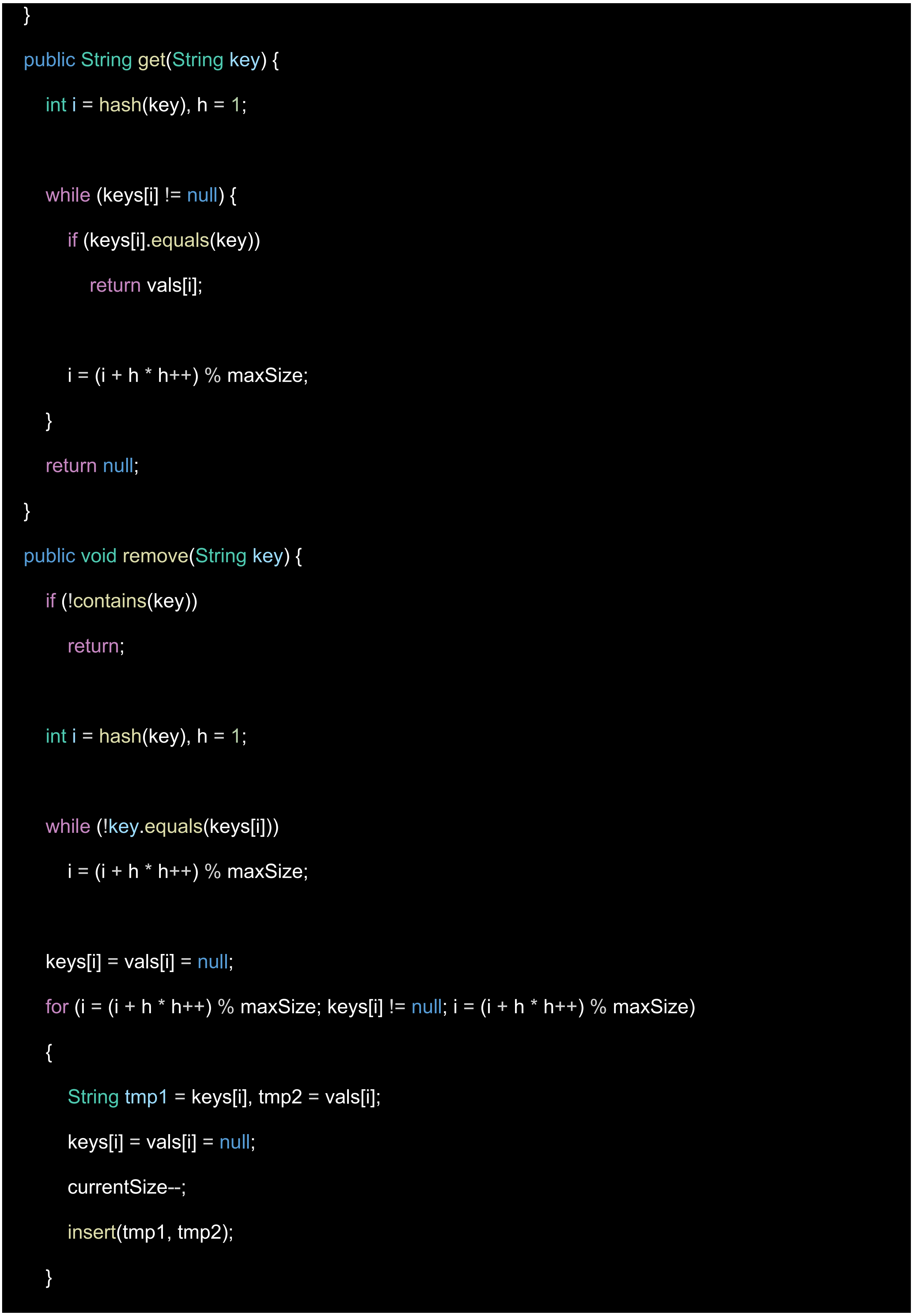
B. Debugging

1. There are three errors in the program, as identified above.
2. To fix these errors, you would need to set breakpoints and step through the code while examining variables like i, h, tmp1, and tmp2. You should pay attention to the logic of the insert, remove and get methods.

3. The corrected executable code is as follows:

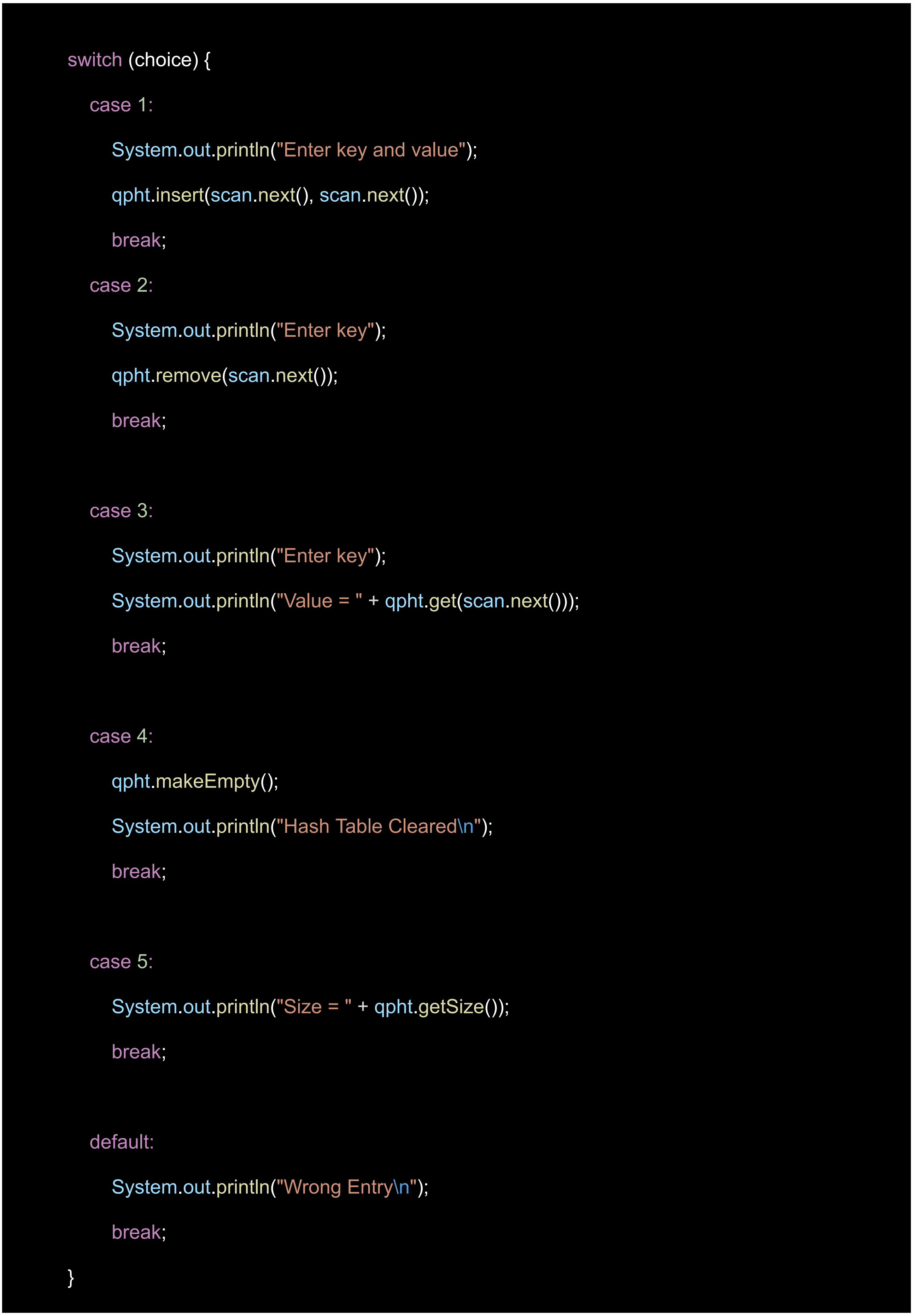
```
import java.util.Scanner;

class QuadraticProbingHashTable {

    private int currentSize, maxSize;


    private String[] keys;

    private String[] vals;


    public QuadraticProbingHashTable(int capacity) {

        currentSize = 0;

        maxSize = capacity;

        keys = new String[maxSize];

        vals = new String[maxSize];

    }


    public void makeEmpty() {

        currentSize = 0;

        keys = new String[maxSize];

        vals = a String[maxSize];

    }


    public int getSize() {

        return currentSize;

    }


    public boolean isFull() {

        return currentSize == maxSize;

    }
```

```
public boolean isEmpty() {
    return getSize() == 0;
}

public boolean contains(String key) {
    return get(key) != null;
}

private int hash(String key) {
    return key.hashCode() % maxSize;
}

public void insert(String key, String val) {
    int tmp = hash(key);
    int i = tmp, h = 1;

    do {
        if (keys[i] == null) {
            keys[i] = key;
            vals[i] = val;
            currentSize++;
            return;
        }
        if (keys[i].equals(key)) {
            vals[i] = val;
            return;
        }
        i += (h * h++) % maxSize;
    } while (i != tmp);
```



```
}
public String get(String key) {
    int i = hash(key), h = 1;

    while (keys[i] != null) {
        if (keys[i].equals(key))
            return vals[i];

        i = (i + h * h++) % maxSize;
    }
    return null;
}
public void remove(String key) {
    if (!contains(key))
        return;

    int i = hash(key), h = 1;

    while (!key.equals(keys[i]))
        i = (i + h * h++) % maxSize;

    keys[i] = vals[i] = null;
    for (i = (i + h * h++) % maxSize; keys[i] != null; i = (i + h * h++) % maxSize)
    {
        String tmp1 = keys[i], tmp2 = vals[i];
        keys[i] = vals[i] = null;
        currentSize--;
        insert(tmp1, tmp2);
    }
```

```
        currentSize--;
    }

    public void printHashTable() {
        System.out.println("\nHash Table: ");

        for (int i = 0; i < maxSize; i++)
            if (keys[i] != null)
                System.out.println(keys[i] + " " + vals[i]);

        System.out.println();
    }
}
public class QuadraticProbingHashTableTest {
    public static void main(String[] args) {
        Scanner scan = new Scanner(System.in);
        System.out.println("Hash Table Test\n\n");
        System.println("Enter size");
        QuadraticProbingHashTable qpht = new QuadraticProbingHashTable(scan.nextInt());
        char ch;

        do {
            System.out.println("\nHash Table Operations\n");
            System.out.println("1. insert");
            System.out.println("2. remove");
            System.out.println("3. get");
            System.out.println("4. clear");
            System.out.println("5. size");
            int choice = scan.nextInt();
```



```
switch (choice) {
    case 1:
        System.out.println("Enter key and value");
        qpht.insert(scan.next(), scan.next());
        break;
    case 2:
        System.out.println("Enter key");
        qpht.remove(scan.next());
        break;

    case 3:
        System.out.println("Enter key");
        System.out.println("Value = " + qpht.get(scan.next()));
        break;

    case 4:
        qpht.makeEmpty();
        System.out.println("Hash Table Cleared\n");
        break;

    case 5:
        System.out.println("Size = " + qpht.getSize());
        break;

    default:
        System.out.println("Wrong Entry\n");
        break;
}
```

```
            qpht.printHashTable();

            System.out.println("\nDo you want to continue (Type y or n) \n");

            ch = scan.next().charAt(0);

        } while (ch == 'Y' || ch == 'y');

    }

}
```

8. Sorting Array

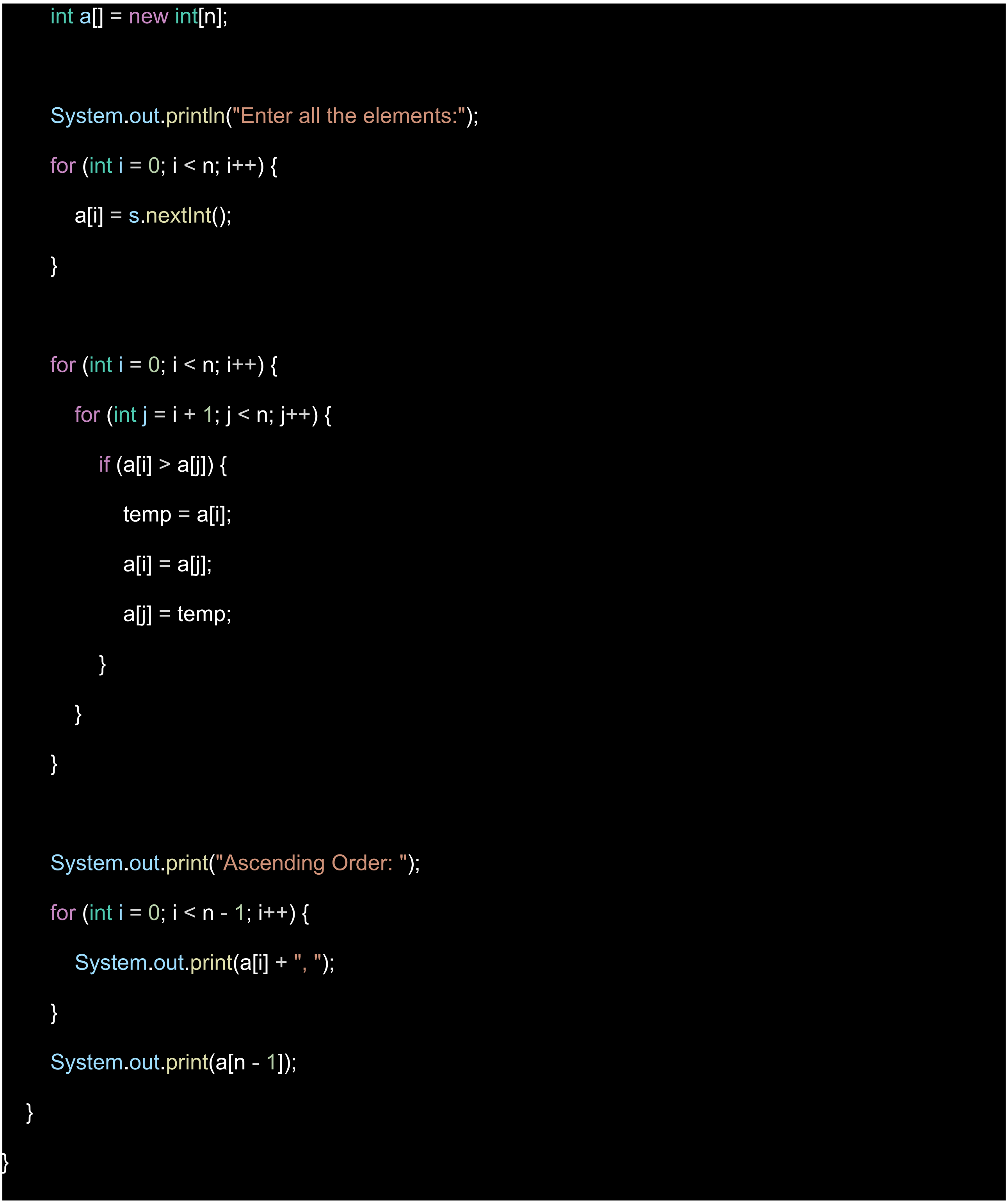
A. Program Inspection

1. Errors identified:
2. Error 1: The class name ”Ascending Order” contains an extra space and an underscore. The class name should be corrected to ”AscendingOrder.”
3. Error 2: The first nested for loop has an incorrect loop condition for (int i = 0; i ¿= n; i++);, which should be modified to for (int i = 0; i ¡ n; i++).
4. Error 3: There is an extra semicolon (;) after the first nested for loop, which should be removed.
5. The most effective category of program inspection would be Category A: Syntax Errors and Category B: Semantic Errors, as there are both syntax errors and semantic issues in the code.
6. Program inspection alone can identify and fix syntax errors and some semantic issues. However, it may not detect logic errors that affect the program’s behavior.
7. The program inspection technique is worth applying to fix the syntax and semantic errors, but debugging is required to address logic errors.

B. Debugging

1. There are two errors in the program as identified above.
2. To fix these errors, you need to set breakpoints and step through the code. You should focus on the class name, the loop conditions, and the unnecessary semicolon.
3. The corrected executable code is as follows:

```
import java.util.Scanner;

public class AscendingOrder {

    public static void main(String[] args) {

        int n, temp;

        Scanner s = new Scanner(System.in);

        System.out.print("Enter the number of elements you want in the array: ");

        n = s.nextInt();
```



```
        int a[] = new int[n];


        System.out.println("Enter all the elements:");
        for (int i = 0; i < n; i++) {
            a[i] = s.nextInt();
        }


        for (int i = 0; i < n; i++) {
            for (int j = i + 1; j < n; j++) {
                if (a[i] > a[j]) {
                    temp = a[i];
                    a[i] = a[j];
                    a[j] = temp;
                }
            }
        }


        System.out.print("Ascending Order: ");
        for (int i = 0; i < n - 1; i++) {
            System.out.print(a[i] + ", ");
        }
        System.out.print(a[n - 1]);
    }
}
```

9. Stack Implementation

A. Program Inspection

1. Errors identified:
2. Error 1: The push method has a decrement operation on the top variable (top–) instead of an increment operation. It should be corrected to top++ to push values correctly.

3. Error 2: The display method has an incorrect loop condition in for(int i=0; i ¿ top; i++). The loop condition should be for (int i = 0; i ¡= top; i++) to correctly display the elements.
4. Error 3: The pop method is missing in the StackMethods class. It should be added to provide a complete stack implementation.
5. The most effective category of program inspection would be Category A: Syntax Errors, as there are syntax errors in the code. In addition, Category B: Semantic Errors can help identify logic and functionality issues.
6. The program inspection technique is worth applying to identify and fix syntax errors, but additional inspection is needed to ensure the logic and functionality are correct.

B. Debugging

1. There are three errors in the program, as identified above.
2. To fix these errors, you would need to set breakpoints and step through the code, focusing on the push, pop, and display methods. Correct the push and display methods and add the missing pop method to provide a complete stack implementation.
3. The corrected executable code is as follows:

```
public class StackMethods {
  private int top;
  int size;
  int[] stack;

  public StackMethods(int arraySize) {
    size = arraySize;
    stack = new int[size];
    top = -1;
  }

  public void push(int value) {
    if (top == size - 1) {
      System.out.println("Stack is full, can't push a value");
    } else {
      top++;
      stack[top] = value;
    }
    }
    public void pop() {
        if (!isEmpty()) {
            top--;
        } else {
            System.out.println("Can't pop...stack is empty");
        }
    }
    public boolean isEmpty() {
        return top == -1;
    }

    public void display() {
        for (int i = 0; i <= top; i++) {
            System.out.print(stack[i] + " ");
        }
        System.out.println();
    }
}
```

10.Tower of Hanoi

A. Program Inspection

1. Errors identified:
2. Error 1: In the line doTowers(topN ++, inter–, from+1, to+1), there are errors in the increment and decrement operators. It should be corrected to doTowers(topN - 1, inter, from, to).
3. The most effective category of program inspection would be Category B: Semantic Errors because the errors in the code are related to logic and function.
4. The program inspection technique is worth applying to identify and fix semantic errors in the code.

B. Debugging

1. There is one error in the program, as identified above.
2. To fix this error, you need to replace the line: doTowers(topN ++, inter--, from+1, to+1);
3. with the correct version:

   doTowers(topN - 1, inter, from, to);

4. The corrected executable code is as follows:

```
public class MainClass {

  public static void main(String[] args) {

    int nDisks = 3;

    doTowers(nDisks, 'A', 'B', 'C');

  }


  public static void doTowers(int topN, char from, char inter, char to) {

    if (topN == 1) {

      System.out.println("Disk 1 from " + from + " to " + to);

    } else {

      doTowers(topN - 1, from, to, inter);

      System.out.println("Disk " + topN + " from " + from + " to " + to);

      doTowers(topN - 1, inter, from, to);

    }

  }

}
```