Operating Systems
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Module: CO-562
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OS 2022 Problem Sheet #5

Problem 5.1: *bank transfers* (2+2 = 4 points)

You are implementing account management software and a fragment of your source code looks like this:

```
#include <pthread.h>

typedef struct account {
    unsigned int number;
    unsigned int money;
    pthread_mutex_t lock;
} account_t;

void transfer(unsigned int money, account_t *from, account_t *to)
{
    pthread_mutex_lock(&from->lock);
    pthread_mutex_lock(&to->lock);

    from->money -= money;
    to->money += money;

    pthread_mutex_unlock(&to->lock);
    pthread_mutex_unlock(&from->lock);
}
```

a) Describe a situation in which this code can deadlock and provide a proof why this code can deadlock.

b) Is it possible to change the code such that deadlocks can be prevented? Show how or why this is not possible. Note that money transfers should be executed concurrently whenever possible.

Problem 5.2: *safe states* (3 points)

A system has $n = 5$ processes, $m = 5$ resource types, and the number of resources for each resource type is given by $t = (6, 17, 9, 10, 7)$. The system is in the following state:

$$M = \begin{bmatrix} 2 & 5 & 3 & 3 & 2 \\ 3 & 5 & 8 & 10 & 1 \\ 4 & 12 & 4 & 9 & 2 \\ 6 & 1 & 4 & 5 & 5 \\ 1 & 2 & 3 & 4 & 5 \end{bmatrix} \quad A = \begin{bmatrix} 0 & 5 & 3 & 1 & 1 \\ 0 & 2 & 1 & 1 & 1 \\ 0 & 7 & 1 & 2 & 1 \\ 3 & 1 & 1 & 1 & 0 \\ 1 & 2 & 3 & 2 & 1 \end{bmatrix}$$

Is the system in a safe state? Provide a calculation to justify your answer.

Problem 5.3: *deadlock detection* (1+2 = 3 points)

A system has $n = 3$ processes, $m = 4$ resource types, and the number of resources for each resource type is given by $t = (2, 2, 1, 3)$. The system is in the following state:

$$A = \begin{bmatrix} 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \end{bmatrix} \quad N = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix}$$

a) Draw the corresponding resource allocation graph.

b) Is the system deadlocked? Provide a calculation to justify your answer.