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FEB EXAM
Project Management and scheduling
Prof. Erik Demeulemeester
February 5, 2022

Instructions for students

- Please write your identification info (student name, student number) on every page!
- **Maximum duration: 3h** (from official starting hour of the exam)
- **Exam type: written, closed book**
- **Only the following auxiliary materials are allowed:**
  - ✓ **Pen**
  - ✓ **Ruler**
  - ✓ **Non-programmable calculator**
- Students are allowed to use their own pen, but should only use the paper provided by the university. Other papers, notebooks, ... are not allowed.
- Mobile telephones and electronic devices should be handed to the invigilators who will keep them for you until the end of the exam. All material such as jackets, backpacks, books and own paper should be left at the back or the front of the examination room.
- For any irregularity of a student, all articles in the irregularities section of the exam regulations apply.
- Please **check** that your exam bundle contains 4 questions. Immediately ask an invigilator for another bundle if this is not the case. Please do not detach any pages from this bundle.
- You can use the back of the pages as scrap paper.
- Only the answers written in the answering boxes will be read. Cross out your scrap text that doesn't need to be corrected (e.g. draft solutions to the exercises). If you would like to have other text that is outside of the answering boxes to be considered as part of the exam, please indicate so clearly by printing in bold 'ANSWER' above it and by drawing a rectangle around it.

Marks

Question 1	Question 2	Question 3	Question 4
/5	/5	/5	/5

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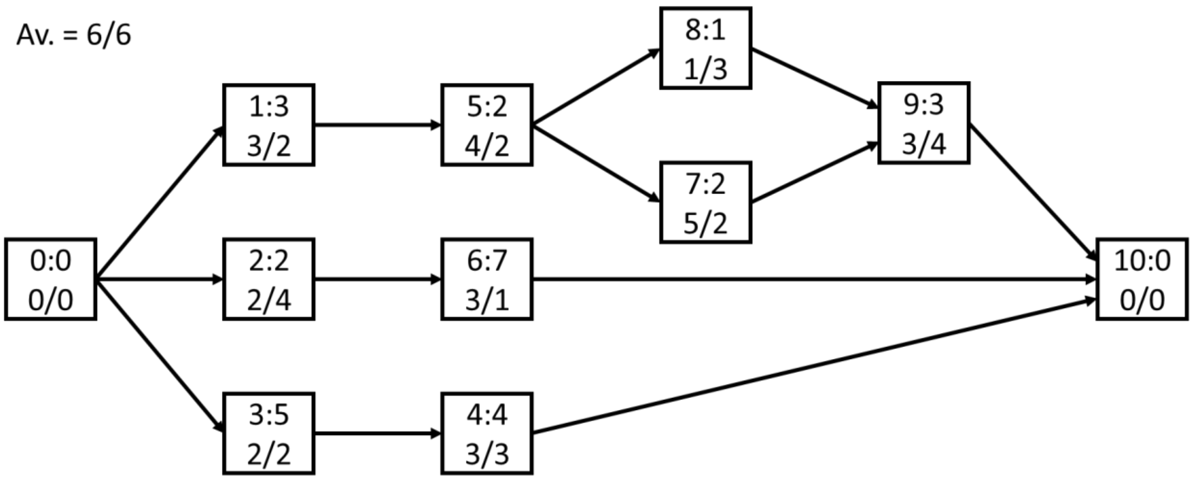
Question 1

Consider the following project network in activity-on-node representation:



The precedence relations are of the finish-start, zero-lag type. Activity 0 and activity 10 are dummy activities. Two renewable resource types have been allocated to the project with constant per period availabilities of 6 and 6 respectively. Each node first contains the activity number and the duration, while on the next line the resource requirements for the two resource types are represented. First calculate the critical path and critical sequence based lower bound at the root node of the branch-and-bound tree (without any additional precedence relations). Afterwards, apply the branch-and-bound procedure of Demeulemeester-Herroelen until the first resource conflict occurs. Compute the minimal delaying alternatives for this resource conflict and calculate for each of them the critical path and the critical sequence based lower bound.

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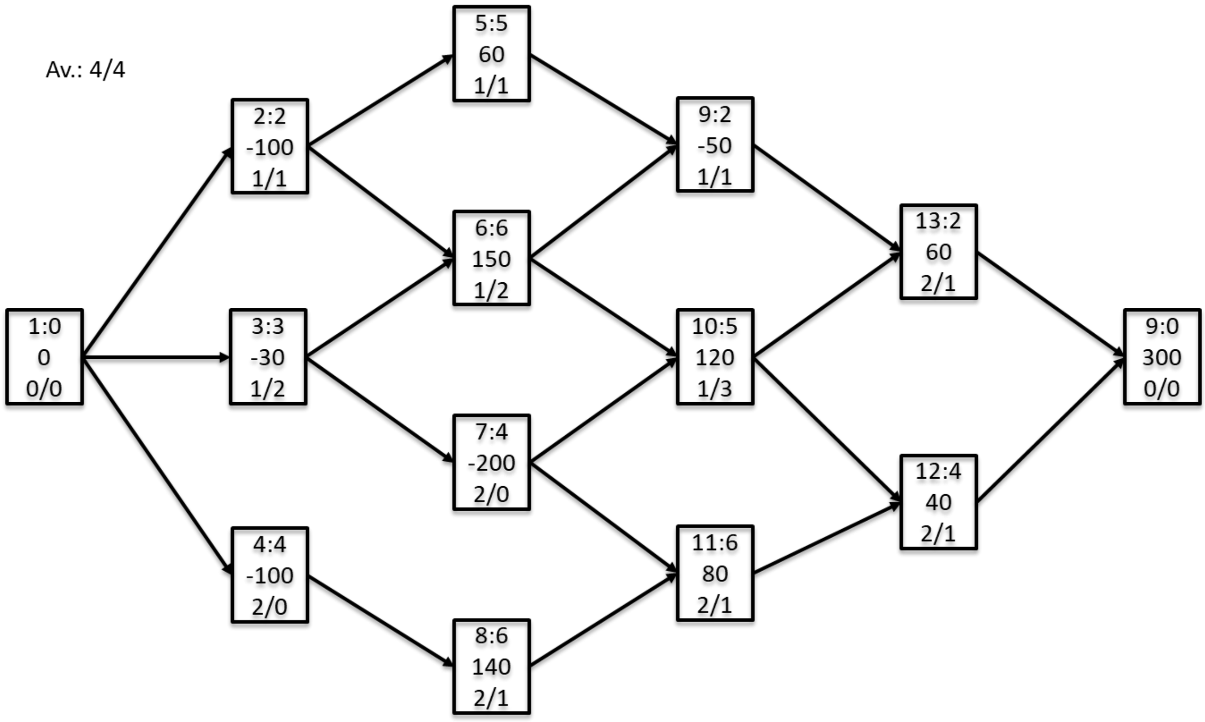
Question 2

Consider the following project network in activity-on-node representation:



The indication of the activity number, duration and resource requirement is identical to the one of the first question, except that now the net incremental cash flow generated at the completion of the corresponding activity is shown on the middle line within each node. The project deadline equals 24 periods. The renewable resources have an availability of 4 and 4 units per period, respectively. The discount rate α amounts to 0.01.

Apply an exact procedure for generating a schedule that yields an upper bound on the net present value of the project. Explain your computational steps in complete detail.

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The upper bound on the net present value of the project equals $ub =$

Draw the resource profiles for the obtained schedule. Identify any resource conflict.

Assume that you want to apply a branch-and-bound procedure for maximizing the project's net present value. Which activities belong to the delaying set? Determine the delaying alternatives that will allow you to identify the nodes of the branch-and-bound search tree to be chosen for branching and draw the corresponding partial search tree (there is no need to calculate the upper bound for each of these delaying alternatives).

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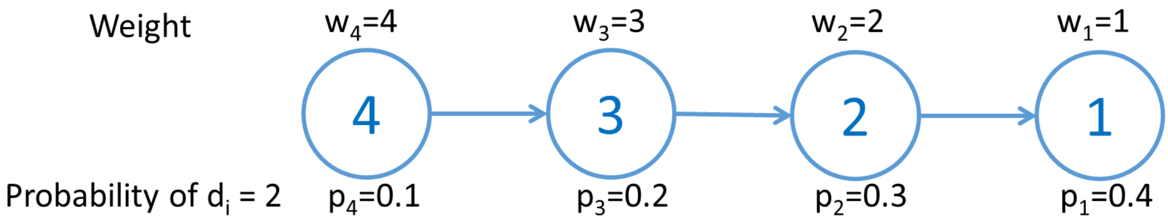
Question 3

Consider the following project network in activity-on-node representation that corresponds to the robust project scheduling problem that we have discussed in session 10 and where the duration of each activity can only take the values 1 or 2:



Assuming that the fixed cost f (the unit cost for the project length of the baseline schedule) equals 10 and the cost of a change c equals 2, calculate the expected cost of the following policy:

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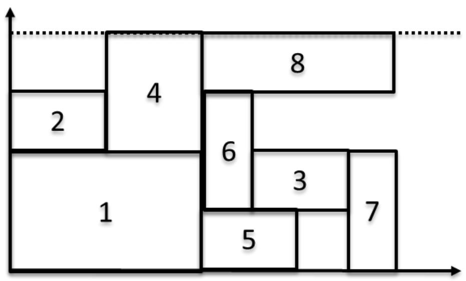
Question 4

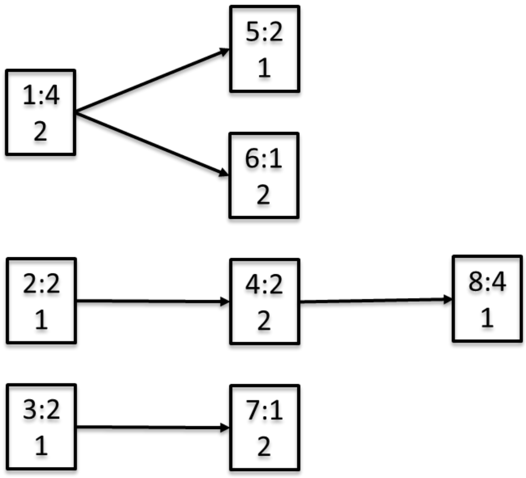
The following (sub)questions are each scored on 1 point (either fill in the number on the dotted lines or indicate the corresponding choice or choices if multiple choices are provided by clearly marking the bullet(s) of your choice):

a) Indicate all the slack calculations that possibly could result in a negative value when only FS = 0 precedence relations are considered for the unconstrained project scheduling problem when represented in activity-on-node format, when $EST_J == LST_J$ for dummy end activity J and where S_i and P_i respectively represent the predecessors and the successors of activity i.

- ○ Total slack: $TS_i = LST_i – EST_i$
- ○ Free slack: $FS_i = \min \{ EST_j \mid j \in S_i \} – EFT_i$
- ○ Safety slack: $SS_i = LST_i – \max \{ LFT_j \mid j \in P_i \}$
- ○ Independent slack: $IS_i = \min \{ EST_j \mid j \in S_i \} – \max \{ LFT_j \mid j \in P_i \} – d_i$

b) To which categories of schedule types belongs the below schedule on the left for the corresponding RCPSP instance on the right?





- ○ Semi-active schedule
- ○ Active schedule
- ○ Non-delay schedule

c) Consider the case where we use priority lists in order to perform a heuristic search for solving an RCPSP instance of 9 real activities and we are performing a two-point cross-over operation with values x_1 of 3 and x_2 of 6 on the following two priority lists:

Father: (3,4,2,1,8,7,5,9,6)
Mother: (2,5,3,4,1,9,6,7,8)

What would be the resulting son of this operation? ……………………………

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d) Mark the bullets where the RCPSP schedule to the right could be cut-set dominated by the one to its left, where the red arrows indicate the time instant that is considered.

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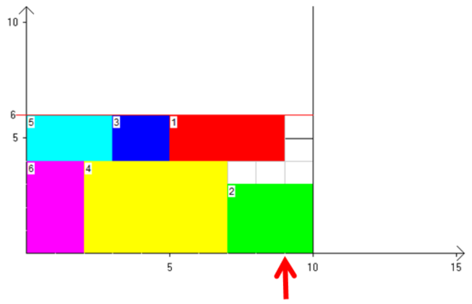 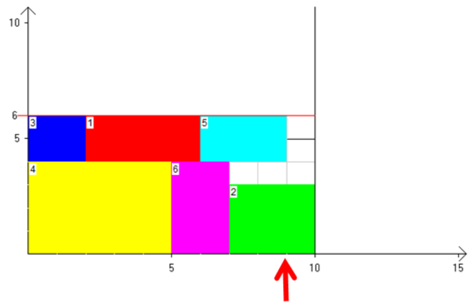

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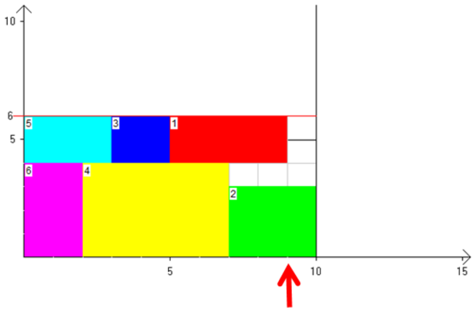 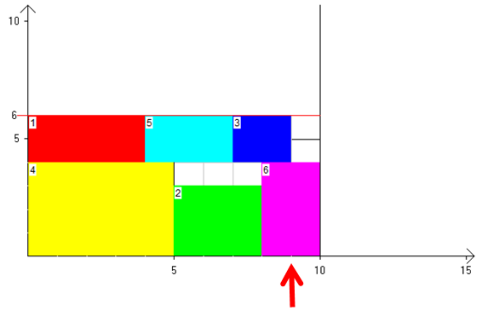

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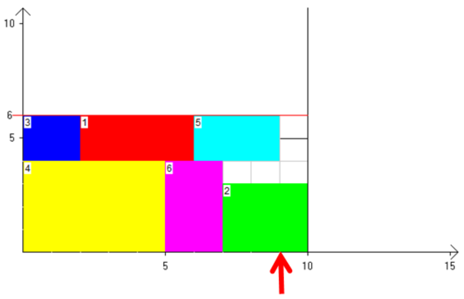 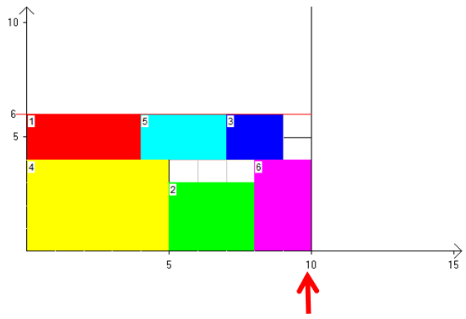

e) Which of the following statements are correct for the schedule and the activity-on-node representation of the RCPSP instance that are indicated on the next page?

- ○ An unavoidable resource arc exists between activities 1 and 2.
- ○ An unavoidable resource arc exists between activities 3 and 4.
- ○ An unavoidable resource arc exists between activities 5 and 6.
- ○ An unavoidable resource arc exists between activities 6 and 7.
- ○ An unavoidable resource arc exists between activities 8 and 9.
- ○ An unavoidable resource arc exists between activities 9 and 10.
- ○ An unavoidable resource arc exists between activities 8 and 10.

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