Question 1 [40 marks total]

UML and design patterns. Consider the design of a simple spreadsheet program. A *spreadsheet* consists of cells arranged into rows and columns. Each *cell* has an expression used to calculate its current value. The *current value* may be either empty, an integer, or the undefined value. An *expression* may be either empty, an integer constant, a reference to another cell, or the sum of two expressions. If either of the two expressions in a sum evaluates to either empty or undefined, the value of the sum is the undefined value.

(a) [8 marks] Design a suitable class representation for (just) the current value of a cell and give the corresponding UML class diagram. Include suitable attributes and operations in your classes.

(b) [12 marks] Identify a suitable design pattern to represent the expressions stored in cells, give a UML class diagram for your representation, and explain how it relates to the design pattern. Include suitable attributes and operations, along with a brief description of the purpose of operations, if it is not clear from their names.

(c) [6 marks] A cell's expression may contain a reference to another cell. State a condition on the overall spreadsheet structure to ensure that such references are valid.
Hint: think of one cell that a cell shouldn't be allowed refer to, and then think about what other cells it shouldn't be allowed to refer to.

(d) [14 marks] When a cell's value is changed, all cells whose expressions reference that cell need to be re-evaluated. Identify a suitable design pattern to handle this situation, give a UML class diagram for your instantiation of the pattern, and explain how it relates to the design pattern. Include suitable attributes and operations, along with a brief description of the purpose of operations, if it is not clear from their names. Although classes within your pattern will overlap with those in part (b), only show classes relevant to this pattern.

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