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| EASJ Notes |
| C# Programming Exercises |
| (used in conjunction with Object-Oriented Programming With C#) |

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# **How to use this exercise set**

This set of exercises is intended to be used in conjunction with the note ***Object-Oriented Programming with C#***. However, they are as such self-contained.

The formulation of each exercise follows a standard pattern:

* **Exercise**: Identifier for the exercise. The first part of the identifier is an acronymed reference to the corresponding chapter in the notes.
* **Project**: A C# project used in the exercise. The specific details of how the project is made available (.zip file, GitHub repository, etc.) may vary from course to course. The projects are self-contained.
* **Purpose**: What aspect of the learning process does this exercise concern.
* **Description**: The “setup” for the exercise, typically some sort of simplified domain-specific context.
* **Steps**: Specific steps in the exercise. The steps often become increasing­ly difficult. Some steps are marked in red. These steps are considered quite difficult.

To get around some technicalities with C# projects that are irrelevant for the begin­ner, some projects contain an extra C# file called **InsertCodeHere.cs**. In that file, an area is delimited by two comments

// The FIRST line of code should be BELOW this line

(sandbox area)

// The LAST line of code should be ABOVE this line

This area is referred to as the “sandbox area” in several exercises. If you are required to put some code in the “sandbox area”, this is the place.

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| **Exercise** | Get.1 |
| **Project** | Sandbox |
| **Purpose** | Reality check – Visual Studio up and running |
| **Description** | The **Sandbox** project is as simple as it gets – we will just use it to verify that your installation of Visual Studio is up and running |
| **Steps** | 1. Load, compile and run the project. 2. Verify that the message ***Hello world!*** Is printed on the screen. |

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| **Exercise** | Pro.1.1 |
| **Project** | MovieManagerV05 |
| **Purpose** | Discuss variables with regards to types and naming |
| **Description** | We imagine this project to be the very first steps in creating an appli­cation for movie management. The application could be used to keep track of relevant information for movies, e.g. a private collection of movies on DVD/Blu-ray (yes, some people still watch movies on physical media ☺). |
| **Steps** | 1. Think about what specific information it could be relevant to store for each movie. 2. For each specific piece of information, think about how you can represent this information. Think about the nature of the infor­mation; is it text, numeric, or something else. 3. In the sandbox area in the project (**InsertCodeHere.cs**), define a variable for each piece of information. You should    1. Choose a proper type for the variable    2. Find a descriptive name for the variable 4. Once you are done, pair up with another student. 5. Switch computer with your partner 6. Review the work of your partner. For each variable in the partner’s project, think about if    1. The purpose of the variable is easy to understand    2. The type seems properly chosen 7. Discuss your findings with your partner. 8. Was there any types of information that were particularly hard to find a good representation for? |

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| **Exercise** | Pro.1.2 |
| **Project** | WebShopV05 |
| **Purpose** | Get some practice in using arithmetic operators |
| **Description** | Part of the business logic in a web shop involves calculating the total cost of an order. The logic for calculating the total cost is as follows:   1. An item has a net price 2. You pay a 10 % tax on top of the net price 3. Shipping costs 49 kr., no matter the number of items 4. There is a credit card fee of 2 % on top of the entire cost, including tax and shipping. |
| **Steps** | 1. Load and open the project – you will see that some variables for the net prices and number of items in an order have already been included. Also, the order details are printed on the screen. 2. The variable **totalPrice** is supposed to contain the total price for the order. You must add the calculations needed to do this, given the logic in the description. 3. Test your solution by varying the number of books, DVDs and games in the order (you do this by assigning new values to the **noOf…** variables) 4. The web shop decides to offer a discount, based on the total number of items you buy:  * If you buy at least 15 items, you get a 5 % discount * If you buy at least 30 items, you get a 10 % discount   The discount is applied to the total price – update the code to include this discount. |
| **Extra info** | Some test examples you can use to verify your solution. Note that the “Total price” is calculated without the discount described in step 4.   |  |  |  |  | | --- | --- | --- | --- | | **Books** | **DVDs** | **Games** | **Total price** | | 8 | 3 | 2 | 711,96 kr. | | 0 | 12 | 4 | 1171,98 kr. | | 23 | 16 | 7 | 2507,16 kr. | |

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| **Exercise** | Pro.1.3 |
| **Project** | WebShopV06 |
| **Purpose** | Get some practice in using logical operators |
| **Description** | Another part of the business logic in a web shop involves deciding if a customer qualifies for certain special offers, based on the order. The shop has four special offers. The logic for qualifying for each offer is:   1. The net total price (no taxes, etc.) is more than 1.000 kr. 2. You have ordered more books than games 3. You have ordered at least 10 items of one kind 4. You have ordered between 10 and 20 DVDs, or at least 5 games |
| **Steps** | 1. Load and open the project – again, some variables are already present. Note the boolean variables **receiveSpecialOffer…** 2. For each of these variables, you must specify a logical expres­sion, corre­sponding to the logic given in the description. 3. Test your solution by varying the number of books, DVDs and games in your order. 4. The web shop decides to offer an extra special offer. You qualify for the extra offer, if you qualify for exactly two of the previous offers. Update your code to include this extra offer. |
| **Extra info** | Some test examples you can use to verify your solution (SO#1 means “special offer 1”, and so on):   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | **Books** | **DVDs** | **Games** | **SO#1** | **SO#2** | **SO#3** | **SO#4** | | 8 | 3 | 2 | false | true | false | false | | 0 | 12 | 4 | false | false | true | true | | 23 | 16 | 7 | true | true | true | true | | 3 | 5 | 4 | false | false | false | false | |

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| **Exercise** | OOP.1.1 |
| **Project** | MovieManagerV10 |
| **Purpose** | Observe how to use an existing class.  Implement simple use of an existing class. |
| **Description** | In this version of the movie manager, a class called **Movie** has been added (in the file **Movie.cs**). It contains an absolute minimum of information about a specific movie. The class is put to use in the sandbox area, where some **Movie** objects are created and used. |
| **Steps** | 1. Load the project, and go directly to the sandbox area. You will see that some code is already present. See if you can figure out what goes on in each line of code. If you hover the mouse cursor over a specific element, you should see some useful information pop up. Make sure you under­stand where    * Objects are created    * Parameters to the constructors are specified    * Properties are used    * Methods are called    * Return values are used 2. Feel free to create additional **Movie** objects, and exercise them a bit (call methods, use properties, etc.) |

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| **Exercise** | OOP.1.2 |
| **Project** | BankV05 |
| **Purpose** | Implement minor additions to existing class. |
| **Description** | The project contains a minimal **BankAccount** class. The class is put to use in the sandbox area, where a **BankAccount** objects is created and used. |
| **Steps** | 1. Load the project, and take a look at the **BankAccount** class. Make sure you understand the elements it contains. Then take a look at how the class is used in the sandbox area. 2. We now want to add an extra property to the **BankAccount** class: the name of the account holder. Add this feature to the class. This will probably involve:    1. Adding an instance field    2. Adding a property    3. Updating the constructor 3. Once the class has been updated, make sure to test the new feature by updating the code in the sandbox area. |

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| **Exercise** | OOP.1.3 |
| **Project** | RolePlayV10 |
| **Purpose** | Implement non-trivial additions to an existing class |
| **Description** | The project contains a **Warrior** class, which is very simple – it only contains a name property. We now need to extend the class with an additional features. |
| **Steps** | 1. Start out by taking a look at the **Warrior** class. Make sure you understand the elements it contains. Specifically, make sure you can identify:    1. An instance field    2. A property    3. The constructor 2. Next, take a look at how the class is used in the sandbox area (**InsertCode­Here.cs**). This is a very small test of the class. 3. We must now extend the **Warrior** class with a “level” feature. The require­ments of this feature are:    1. All warriors start at level 1.    2. The level can be retrieved freely, but not changed freely.    3. It must be possible to increment the level, i.e. increase the value of the level by 1. 4. Implement this feature in the **Warrior** class. You will need to consider if    1. An extra instance field is needed (Hint: we need to store the current level of a **Warrior** somewhere)    2. An additional property is needed (if so, do we need both the **get** and the **set** part? Hint: We only require that the value of the level can be retrieved, not changed)    3. The constructor should be updated (Hint: The construc­tor should initialise all instance fields with a well-defined value. What would that value be, given requirement 3a?).    4. A method for incrementing the level is needed (Hint: the level should always just be increased by 1). 5. Test the updated **Warrior** class, by adding some code to the sandbox area. |

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| **Exercise** | OOP.1.4 |
| **Project** | RolePlayV11 |
| **Purpose** | Implement non-trivial additions to an existing class |
| **Description** | The project contains a **Warrior** class, including the functionality described in the previous exercise (a “level” feature). |
| **Steps** | 1. We must now extend the class with a “hit points” feature. Details of this feature are:    1. Hit points are set individually when a warrior is created.    2. Hit points can be retrieved freely, but not changed freely.    3. It must be possible to decrease hit points by a specified amount. This corresponds to the warrior being damaged by someone 2. Implement this feature in the **Warrior** class. You will need to consider if    1. An extra instance field is needed (Hint: we need to store the current hit points of a **Warrior** somewhere)    2. An additional property is needed (if so, do we need both the **get** and the **set** part? Hint: We only require that the value of the hit points can be retrieved, not changed)    3. The constructor should be updated (Hint: The construc­tor should initialise all instance fields with a well-defined value. What would that value be, given requirement 3a? How can we provide this value to the constructor? Extra hint: How is the value of the name provided to the constructor?).    4. A method for decreasing the hit points is needed (Hint: how can the specific amount to decrease the hit points with be provided to the method?). 3. Implement a property called **Dead**, which returns a boolean value. The property should return **true** if hit points are equal to or below zero (Hint: we only need the **get** part of this new property). 4. Test the updated **Warrior** class, by adding some code to the sandbox area. |

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| **Exercise** | OOP.1.5 |
| **Project** | ClockV10 |
| **Purpose** | Implement a class from scratch, including use of the class |
| **Description** | This project contains an empty class definition **Clock**. Your job is to implement the class, given the below requirements:   1. The clock should keep track of hours and minutes. 2. The clock should use the 24-hour system. 3. It must be possible to set the clock to a specific time. 4. It must be possible to retrieve the current time from the clock. 5. It must be possible to advance the clock by a single minute. |
| **Steps** | 1. Implement requirements 1-4. This will involve figuring out what instance fields, constructor, properties and methods you need for this. Remember to include code for testing the class. 2. Implement requirement 5. In this case, it becomes quite important to choose relevant test cases. |

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| **Exercise** | OOP.1.6 |
| **Project** | DiceGame |
| **Purpose** | Work with a project containing collaborating classes |
| **Description** | This project contains two classes: **Die** and **DiceCup**. The **Die** class represents a 6-sided die, and is completed. The **DiceCup** class needs a bit of work to be complete. The **DiceCup** class uses the **Die** class. |
| **Steps** | 1. Take a look at the **Die** class. It is complete, and fairly simple. Note that we use another class in the **Die** class, called **Random**. This class is from the .NET class library. 2. Open the **DiceCup** class. Note how the class contains two instance fields of type **Die**. Also note the constructor – what happens there? 3. The **DiceCup** class is not complete. Implement the **Shake** method and the **TotalValue** property, as specified in the comments in the code. Test that your code works as expected, by creating and using a **DiceCup** object in the sandbox area. 4. How much would we need to change in order to have a dice cup with three dice? 5. When we create a **DiceCup** object, we would also like to be able to specify the number of sides the dice should have. Implement the necessary changes in **Die** and **DiceCup** needed to enable this feature. |

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| **Exercise** | OOP.1.7 |
| **Project** | StaticExamples |
| **Purpose** | Defining and using static classes, methods and instance variables. |
| **Description** | The project contains the class **ListMethods**, which defines two methods **FindSmallestNumber** and **FindAverage**. The names should hopefully indicate what they do. Code that tests the class is included in the sandbox area. The class is tested in the traditional way; create an object, and call methods on the object. |
| **Steps** | 1. Change the **ListMethods** class into a static class. Remember that a static class can only contain static methods. 2. Modify the code in the sandbox area , such that it uses the **ListMethods** class as a static class. The output of running the application should of course be as before. 3. The project also contains a simple class **Car** (see the code). We would now like to track how the class is used. More specifically, we wish to track the number of    1. **Car** objects that have been created    2. Uses of the property **LicensePlate**    3. Uses of the property **Price** 4. Add static instance fields to the **Car** class, to enable the tracking described above. Increment the value of each variable at the appropriate place in the class. 5. Add a static method that can print out the values of the static instance fields. It could be called **PrintUsageStatistics**. 6. Test that your additions work, by including some test code in the sandbox area. Create and use some **Car** objects, and finally call the static method to observe the usage statistics. |

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| **Exercise** | Pro.2.1 |
| **Project** | BankV10 |
| **Purpose** | Use simple **if**-statements in an existing class. |
| **Description** | This project contains a minimal **BankAccount** class, that sort of works. However, it has some problems… |
| **Steps** | 1. Test the **BankAccount** class, by adding code in the sandbox area. Specifi­cally, make some tests that make the balance go negative. 2. Now change the code in the **Withdraw** method, such that a withdrawal is only done if the balance is larger than or equal to the given amount. Remem­ber to test that the change works as expected. 3. This makes the **BankAccount** class more realistic, but there are still pro­blems – you can call both **Withdraw** and **Deposit** with negative amounts (try it), which does not make much sense. Make changes to both methods, such that they only perform a withdrawal/deposit if the given amount is positive. Remember that for the **Withdraw** method, the change made in part 2 must still work! 4. Test that all your changes work as expected. 5. If we call **Withdraw** or **Deposit**, and detect an error situation, we don’t do anything… What should we do? |

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| **Exercise** | Pro.2.2 |
| **Project** | WTF |
| **Purpose** | Use **if-else**-statements. Use method calls creatively. |
| **Description** | This project contains a class called **MysticNumbers**, with a single method **ThreeNumbers**. All that is known about **ThreeNumbers** is that it takes three integers as input, and returns one of them |
| **Steps** | 1. By reading the code for **ThreeNumbers**, try to figure out what it does. Write some test code to see if you are right. 2. Write and test a new method **TwoNumbers**, that does the same thing as **ThreeNumbers**, but now only for two numbers. 3. Write and test a new method **FourNumbers**, that does the same thing as **ThreeNumbers**, but now for four numbers (tip – you can probably use the method **TwoNumbers** to make the code fairly short and easy). 4. Rewrite **ThreeNumbers** to use the **TwoNumbers** method. What code do you like best – the original code or the new code? |

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| **Exercise** | Pro.2.3 |
| **Project** | WeatherStationV10 |
| **Purpose** | Use multi-**if-else**-statements. |
| **Description** | This project contains a class called **Barometer**, containing two properties **Pressure** and **WeatherDescription**. The latter property gives an old-fashioned description of the weather, as a function of the pressure, according to this table:   |  |  | | --- | --- | | **Pressure** | **WeatherDescription** | | Below 980 | Stormy | | 980-1000 | Rainy | | 1000-1020 | Changing | | 1020-1040 | Fair | | Above 1040 | Very dry | |
| **Steps** | 1. Implement the property **WeatherDescription**, according to the table in the description. 2. Test your code. |

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| **Exercise** | Pro.2.4 |
| **Project** | WhileLoopsBaseCamp |
| **Purpose** | Get some experience with **while**-loops |
| **Description** | The project contains some counter-controlled **while**-loops, and some number sequences that should be generated using **while**-loops. |
| **Steps** | 1. In the sandbox area, four **while**-loops (Case 1-4) are given. Try to figure out what the output from each loop will be. When ready, uncomment the line in each loop that prints the current value of the counter variable, and see if you were right. 2. Next follows Case 5-8. Here you must implement a **while**-loop yourself, to produce the number sequence given in the comment for each case. |

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| **Exercise** | Pro.2.5 |
| **Project** | CorrectChangeAutomat |
| **Purpose** | Use **while**-loops for a more complicated problem |
| **Description** | This exercise is about calculating the correct change when a customer pays a due amount with too much cash (yes, some people still pay with cash…).  Example: A customer has to pay 266 kr., but pays 500 kr.. The custo­mer must then receive 234 kr. in change. The tricky part is to figure out how to pay this amount using ordinary bills and coins, and paying back as few bills and coins as possible. In this example, the correct way to pay back correct change would be:   * One 200-kr bill * One 20-kr coin * One 10-kr coin * Two 2-kr coins |
| **Steps** | 1. Implement code to calculate and print out the correct change. To keeps things simple, we assume that you only use 100-kr bills, 10-kr coins and 1-kr coins. Remember to test your code with some different values for change. You can just add the code in the sandbox area. 2. Once the above problem is solved, include some more bills and coins, like 50-kr bills, 5-kr coins, etc.. 3. If you used while-loops for solving the problem: Try to solve the problem without using loops. |

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| **Exercise** | Pro.2.6 |
| **Project** | RolePlayV20 |
| **Purpose** | Get further experience with **while**-loops. Work with a project involving several classes. |
| **Description** | The project is supposed to model a very simple game, where a hero can battle against a beast, until either beast or hero is dead! The project contains four classes, which are described in general terms here – see the code for more details:   * The **NumberGenerator** class, with the method **Next**. This is a helper class for generating random numbers. * The **BattleLog** class, where individual strings can be “saved”, and later on printed out on the screen. * The **Hero** class, which models a game character. It is a very simple model, since it just has a number of hit points. * The **Beast** class, which also models a game character, in a way similar to the **Hero** class.   Even though this is a very simple setup, it does include fundamental game mechanics from many popular role-playing games. |
| **Steps** | 1. Study the classes in details, so you are sure of what they can do and how they work. Note how the **Hero** and **Beast** classes make use of the **NumberGenerator** and **BattleLog** classes. 2. See if you can figure out how to code a battle between a **Hero** and a **Beast** (until the death!). A bit of code is present in the sandbox area, but it obviously needs to be extended. 3. When you can make the two objects battle each other, there are a number of things to consider afterwards:    1. It seems like the **Hero** wins most of the time (depending of course on how you coded the battle…). Why is that? How could we make the battle more fair?    2. The damage dealt by the **Hero** is always between 10 to 30 points. How could we change that? Could we even let the creator of the **Hero** object decide this interval? Could this also be done for the number of initial hit points?    3. Do we really need separate classes for **Hero** and **Beast**? |

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| **Exercise** | Pro.2.7 |
| **Project** | DrawShapes |
| **Purpose** | Get some experience with **for**-loops |
| **Description** | This exercise is about trying to draw some simple shapes on the screen, using **for**-loops to get the job done. A very simple class **DrawingTool** is provided to help with this. |
| **Steps** | 1. Study the class **DrawingTool**. As you can see, it is very simple. Why is the class (and the methods) static? 2. Using **for**-loops and the **DrawingTool** class, see if you can create code to draw the shapes A to E, as defined in the comments in the sandbox area. NOTE: The shapes get increasingly hard to draw… |

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| **Exercise** | Pro.2.8 |
| **Project** | ListBaseCamp |
| **Purpose** | Get some experience with methods in the **List** class. |
| **Description** | This exercise is about predicting the result of applying some methods of the **List** class to a **List** object, and also about writing some code to use a **List** object |
| **Steps** | 1. In the sandbox area, a **List** object is created, and some elements are added and removed. At four points in the code (Case 1-4), you must predict the outcome of the **WriteLine** statement. When ready, you can uncomment the **WriteLine** statement, and see if your prediction was correct. 2. Following the cases above, four more cases are given (Case 5- 8), where you must write code that use the **List** object, to retrieve various information about the elements in the list. Details for each case are given as comments in the code. |

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| **Exercise** | Pro.2.9 |
| **Project** | RolePlayV21 |
| **Purpose** | Get some experience with the **List** class. |
| **Description** | This exercise picks up where Pro.2.6 let off. Now the Hero must face a greater challenge! (or maybe he’s just farming..).  The project RolePlayV21 is identical to the solution to Pro.2.6. The Hero can do a battle against a Beast, and both classes now take several parameters in their constructor. |
| **Steps** | 1. Change the code in InsertCodeHere.cs, to do a battle between a single Hero and an army of Beasts. (Hint: Check out the new, fancy **BeastArmy** class…). You might need to adjust the strength of Beasts, to give the Hero a chance… |

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| **Exercise** | Pro.2.10 |
| **Project** | LibraryV10 |
| **Purpose** | Use the **List** class. Implement linear search. |
| **Description** | This exercise illustrates the concept of a catalog. A catalog is a class that can store and use data of a certain type, without revealing the specific representation of data to the user of the catalog.    The project contains the simple domain class **Book** (we consider the isbn number to be a “key” for **Book**, i.e. no two **Book** objects can have the same isbn number). Also, it contains the (incomplete) catalog class **BookCatalog**. The three public methods in **BookCatalog** allow the user to store and use **Book** objects in a simple way (see the comments in the code for more details about each method). |
| **Steps** | 1. Study the test written in the sandbox area, and figure out what you expect the test to output. 2. Complete the three methods in the **BookCatalog** class. 3. Run the application, and see if the output of the test matches your expec­tations (if not, you will have to examine the test and your code once again…). 4. Is there anything in the code that prevents a user from adding two **Book** objects with the same isbn value? 5. How could you prevent that **Book** objects with the same isbn value are added to the catalog? |

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| **Exercise** | Pro.2.11 |
| **Project** | LibraryV11 |
| **Purpose** | Use the **Dictionary** class. |
| **Description** | ***NOTE: This exercise is intentionally almost identical to Pro.2.10***  This exercise illustrates the concept of a catalog. A catalog is a class that can store and use data of a certain type, without revealing the specific representation of data to the user of the catalog.    The project contains the simple domain class **Book** (we consider the isbn number to be a “key” for **Book**, i.e. no two **Book** objects can have the same isbn number). Also, it contains the (incomplete) catalog class **BookCatalog**. The three public methods in **BookCatalog** allow the user to store and use **Book** objects in a simple way (see the comments in the code for more details about each method). |
| **Steps** | 1. Study the test written in the sandbox area, and figure out what you expect the test to output. 2. Complete the three methods in the **BookCatalog** class. 3. Run the application, and see if the output of the test matches your expec­tations (if not, you will have to examine the test and your code once again…). 4. Is there anything in the code that prevents a user from adding two **Book** objects with the same isbn value? 5. How could you prevent that **Book** objects with the same isbn value are added to the catalog? |

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| **Exercise** | Pro.2.12 |
| **Project** | SchoolAdministrationV10 |
| **Purpose** | Use the **Dictionary** class. Work with an application containing several classes. |
| **Description** | The project contains the class **Student**. This is a simple representation of a student, with three instance fields; id, name and test scores. The first two are simple, but the “test scores” field is a **Dictionary**, holding key-value pairs of course names (string) and scores (int).  The project also contains the class **StudentCatalog**. This class is sup­posed to be able to retrieve various information about the students; for this purpose, an instance field **\_students** of type **Dictionary** is used to hold key-value pairs consisting of ids and **Student** objects (since a student is uniquely identified by an id) |
| **Steps** | 1. The class **Student** is complete, and you need not change anything in it. However, take a good look at the **Student** class anyway, and make sure you understand how the methods work. Pay particular attention to the property **ScoreAverage**. 2. Look in the class definition of **StudentCatalog**. It contains five properties/methods (**Count**, **AddStudent**, **GetStudent**, **GetAverageForStudent**, **GetTotalAverage**) that are not completed. Add code to complete these methods, according to the specification given in the comments in the code. 3. Code that tests the **StudentCatalog** class has been added in the sandbox area,. Run the application, and check that the **Student­Catalog** class behaves as expected. |

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| **Exercise** | Pro.2.13 |
| **Project** | Flinter |
| **Purpose** | Use enumerations |
| **Description** | **Flinter** is supposed to be the start of a new dating app. You can create profiles for those you are interested in meeting.  In the project, the class **Profile** has been included. The class contains instance fields for gender, eye color, hair color, and height. You can thus create a **Profile** object by specifying values for each of these four fields in the class constructor. Furthermore, you can get a text description of a **Profile** object by using the property **GetDescription**. |
| **Steps** | 1. Code that tests the **Profile** class is as always included in sandbox area. Examine the code in the **Profile** class definition, and see if you can predict the outcome of running the test. 2. Running the test reveals some problems. In two cases, we have specified hair color where we should have specified eye color, and vice versa (unless you really want a partner with white eyes and blue hair…), and in one case, we have specified a height category that doesn’t exist. Change the **Profile** class definition by adding enumerated types for gender, eye color, hair color and height category. Use these new types for the four instance variables. The constructor needs some changes as well. Also consider if you still need the properties **GenderDescription** and **HeightDescription**. 3. Change the code in the sandbox area , so it is compatible with the rede­signed **Profile** class. Observe how it is now only possible to specify legal values for each type. 4. Reflect a bit on the changes. Is there anything in the new code that is more complicated than it was in the original code? Was it always relevant to use an enumerated type? |

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| **Exercise** | Pro.2.14 |
| **Project** | CalculationSimulation |
| **Purpose** | Improve code structure by replacing values with constants, instance fields and parameters |
| **Description** | The project contains a simple simulation of a calculation. The inten­tion is to simulate a calculation that takes about half a second. The calculation takes two values x and y, and returns an integer value.  In order to speed up the calculation, a “cache” class is also provided. The idea is that once a calculation has been done, the result can be stored in the cache, from which it can be retrieved very quickly. See the code for further details. |
| **Steps** | 1. The code is set up to do calculations in a 5x5 table (that is, x and y can be numbers between 0 and 4, both included). How many places in the project would you have to change something, if you want to do calculations in a 10x10 table instead? 2. Change the code, such that you get rid of all the instances of the number 5 in the methods. This could be done by using constants, instance fields and parameters. 3. It seems like -1 means “no value”. Change the code, such that the value -1 does not occur in the methods. 4. Are there other values that are candidates for being replaced with constants or parameters? If so, make the necessary updates to the code. |

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| **Exercise** | Pro.2.15 |
| **Project** | WebShopV10 |
| **Purpose** | Improve code structure by creating new methods |
| **Description** | Part of the business logic in a web shop involves calculating the total cost of an order. The logic for calculating the total cost is found in the code in the project.  In the project, the **Order** class contains an item list. For simpli­city, the item list just contains the net price for each item in the order. The class also contains a property **TotalOrderPrice** for calculating the total price for the order. |
| **Steps** | 1. The implementation of the **TotalOrderPrice** property is less than optimal. Rewrite it, with the intent of:    1. Removing duplicate code    2. Making the method easier to understand |

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| **Exercise** | OOP.2.1 |
| **Project** | EmployeesV10 |
| **Purpose** | See inheritance in action. Reorganise existing code to use inheritance. Call base class constructors. |
| **Description** | The project contains two existing classes **Teacher** and **ITSupporter**. They have quite a lot in common, so there is a lot of code duplication to get rid of. |
| **Steps** | Reorganise the code using inheritance     1. Create a new class **Employee**, that contains the common parts from **Teacher** and **ITSupporter**. 2. Let **Teacher** and **ITSupporter** inherit from **Employee**. The code in InsertCodeHere.cs should work as before. Remember that the derived classes will need to call the base class constructor. |

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| **Exercise** | OOP.2.2 |
| **Project** | RolePlayV23 |
| **Purpose** | Override existing methods in derived class |
| **Description** | The project contains a working role-play system. Any character in the game is represented by an object of the class **Character**. |
| **Steps** | 1. Get an overview of the application. The most interesting class is the **Cha­racter** class, which implements a generic game charac­ter. Also note the code in InsertCodeHere.cs, where two teams with two members are set up for battle. 2. Create a class **Defender**, which derives from **Character**. A **Defender** has a 50 % chance of having the received damage reduced by 40 %. This means that the **ReceiveDamage** method must be overrided. Once you have crea­ted the class, update the code in InsertCodeHere.cs to include a **Defender** on each team. 3. Create a class **Damager**, which derives from **Character**. A **Damager** has a 40 % chance of dealing double damage. This means that the **DealDamage** method must be overrided. Once you have created the class, update the code in InsertCode­Here.cs to include a **Damager** on each team. 4. Can we organise the code better, in order to e.g. make calls to the base class methods for dealing and receiving damage? (Maybe the calculation and the logging should be separated into separate methods). |

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| **Exercise** | OOP.2.3 |
| **Project** | SimpleGeometry |
| **Purpose** | Override abstract methods. See polymorphic behavior in action. |
| **Description** | The project contains the (abstract) class **Shape**, with an abstract property **Area**. The class also contains a static method **FindTotalArea**, that should calculate the total area of a list of shapes |
| **Steps** | 1. Create two classes **Circle** and **Rectangle**. Both classes should inherit from **Shape**, and therefore implement the abstract property **Area**. You also need to figure out what instance fields, etc. the two classes need (if you need the value of π (pi), you can get it by writing **Math.PI**). 2. Implement the **FindTotalArea** method properly, such that it finds the total area of a list of shapes. 3. In the sandbox area, fill in some shapes in the given list, and see if your implementation works as expected |

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| **Exercise** | OOP.2.4 |
| **Project** | FilteringV10 |
| **Purpose** | Use interfaces to generalise code |
| **Description** | The project contains a class **Filter**, with a **FilterValues** method. The method filters out values higher than 10 from a list of integers. The project also contains an interface ***IFilterCondition***. |
| **Steps** | 1. Figure out how you can use the interface ***IFilterCondition*** to change the **FilterValues** method, into a method that can filter a list of integers accor­ding to any condition. That is, the condition itself has to somehow become a parameter to the method. Try out your solution with a couple of condi­tions. 2. Figure out how you can apply several filter conditions to a list in a single method call. 3. Filtering is a very generic operation. Maybe some of the .NET collection classes already support filtering…? |

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| **Exercise** | OOP.2.5 |
| **Project** | CarDealershipV05 |
| **Purpose** | Override methods from **Object** class. |
| **Description** | The project contains a simple class **Car**, which contains a few proper­ties. In the sandbox area, we attempt to print out **Car** objects, and perform some comparisons between **Car** objects. |
| **Steps** | 1. Run the program as-is, and observe the result. Can you figure out when the comparisons return **true**? 2. In the **Car** class, uncomment the **Equals** method (only that method), and run the program again. What has changed? 3. Uncomment the rest of the code in the **Car** class, and run the program again. What has changed? 4. The printing of **Car** objects is still not very satisfying. In the **Car** class, over­ride the **ToString** method, so that it returns a string giving a reasonable description of the **Car** object. Run the program again, and see what difference it makes. |

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| **Exercise** | OOP.2.6 |
| **Project** | CompanyV10 |
| **Purpose** | Use inheritance when creating several classes |
| **Description** | The project contains very little from the start. There is an **Employee** class with a **Name** property, and some abstract properties. Concerning salary calculation, only some very general rules exist:   * Part of the salary is a fixed amount * Part of the salary is a bonus amount * The bonus amount is paid if a certain condition is met   Specific definitions of the rules should be defined in classes that inherit from **Employee** |
| **Steps** | 1. Create a **Worker** class. The class should inherit from **Employee**. For a worker, the below rules apply:  * A worker works a fixed amount of hours per month * A worker is paid a fixed amount per hour * A worker does not receive any sort of bonus  1. Create a **Manager** class, also inheriting from **Employee**. The rules for salary calculation are more vague for a manager:  * A manager has a fixed monthly base salary * A manager has a fixed monthly bonus   The condition for when the bonus is paid out may vary, depending on the specific type of manager (NB: This implies that **Manager** also becomes an abstract class).   1. Create a **JuniorManager** class, that inherits from **Manager**. A junior mana­ger will have the bonus paid out if (s)he has worked at least 180 hours during the month. 2. Create a **SeniorManager** class, that inherits from **Manager**. A senior mana­ger will have the bonus paid out if (s)he has a performance evaluation of at least 6 during the month |

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| **Exercise** | GUI.1.0 |
| **Project** | ExamAdmV10 |
| **Purpose** | Create data bindings between GUI controls |
| **Description** | The project contains a simple GUI for an exam administration system. In this version, you can just type in a name, a subject and a test score for an exam. The data is entered through two text boxes and a slider control. |
| **Steps** | 1. Open the project, and open the MainPage.xaml file. Even though the file contains quite a bit of XAML, we only need to focus on the three named controls, with the names **student­Name**, **subject** and **score** (two **TextBox** controls and a **Slider** control). Make sure you can find these three controls in the XAML code. 2. We want to bind three **TextBlock** controls to the value of the three named controls. The three **TextBlock** controls are all part of the top line of the GUI, which consists of a total of six **TextBlock** controls. For each of the three relevant **TextBlock** controls, figure out which specific named control to bind to. 3. Now create the actual bindings, using the syntax described in the notes (for a **Slider**, you bind to the **Value** property; for a **TextBox**, you bind to the **Text** property). 4. Test that your bindings work as expected |

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| **Exercise** | GUI.1.1 |
| **Project** | ExamAdmV11 |
| **Purpose** | Create data bindings between GUI controls and a domain object |
| **Description** | The project is identical to the project from ExamAdmV10, except that a class **Student** has been added. Right now, the constructor in **Student** just sets the properties to some fixed values. |
| **Steps** | 1. Open the MainPage.xaml file, and add a data context to the **Page** control, specifying **Student** as the data context. See the notes for the syntax for adding a data context. 2. Bind the three relevant **TextBlock** controls (the same as in the previous exercise) to the corresponding properties on the **Student** class. Again, see the notes if you cannot remember the syntax for this. 3. Also create bindings for the three named controls, such that each control – or more precisely; the relevant property in each control – is bound to the corresponding **Student** property. 4. Run the application, and check that the bindings work as expected. Try to change the values as well. Are the changes reflected in the text line at the top? |

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| **Exercise** | GUI.1.2 |
| **Project** | ExamAdmV12 |
| **Purpose** | Create two-way data bindings between GUI controls and a domain object |
| **Description** | The project starts off where the previous exercise left off. The project does contain data bindings, but changes in the values are still not reflected in the rest of the GUI. |
| **Steps** | 1. Open and run the application. Confirm that changes in the values are not reflected in the top text line. 2. Open the **Student** class. All three properties now have a **set**-part as well. Now let **Student** inherit from the **INotifyProperty­Changed** interface, and implement the **OnPropertyChanged** method (if ReSharper if installed, Visual Studio can generate the code for you. If not, you can simply copy-paste the code from the notes). 3. Run the application again – are value changes now reflected in the text line? 4. For each property in **Student**, add a call to **OnPropertyChanged** to the **set**-part of the property, after the value has been set. 5. Run the application again – are value changes now reflected in the text line? 6. For each of the three bindings for the named controls (not the **TextBlock** control), update the binding mode to **TwoWay**. 7. Run the application again – are value changes now reflected in the text line? 8. Why don’t we need to update the three **TextBlock** bindings to being **TwoWay**? |

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| **Exercise** | GUI.1.3 |
| **Project** | ExamAdmV13 |
| **Purpose** | Create data bindings between collection-oriented GUI controls and domain object collections |
| **Description** | We now introduce a **StudentCollection** into the application. For now, it contains a **Student** list (with one entry), and a subjects list (initia­lised with five entries). The class also has a property **SelectedStudent**, that for now just returns the single entry in the **Student** list. |
| **Steps** | 1. Open the **StudentCollection** class, and make sure you under­stand the instance fields and properties it contains (except the **NewSubject** property) 2. Open the MainPage.xaml file. The bindings are now a bit more complex, since the data context is now **StudentCollection**. Most properties are now bound to the corresponding property on the **SelectedStudent** property (i.e. **Student** object). Make sure you understand the new bindings. 3. Run the application (ignoring the two extra lines beneath “Score”). The application does work, since updates to **name**, **score** and **subject** are reflected in the top text line (try it!). 4. In the “New subject” line, the intention is that when a new subject is entered, it should show up in the Subject combo-box. Confirm that this is not the case right now (remember that you must leave the text box, before the update is triggered). 5. The “No. of subjects” field tells how many entries the **\_subjects** list in **StudentCollection** contains. Right now, the number stays at 5. Figure out how to create a binding for the text box next to the “New subject” text, such that a new entry is indeed added to **\_subjects** (Hint: Take a look at the **NewSubject** property in **StudentCollection**). 6. Once this binding works, the number should increase every time a new subject is added. Still, the new subjects do not show up in the combo-box. Figure out why this is the case, and fix it. (Hint: Are we using the correct collection class for \_**subjects**?) |

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| **Exercise** | GUI.1.4 |
| **Project** | ExamAdmV14 |
| **Purpose** | Create a data template for presenting objects in a **ListView** |
| **Description** | The application main view contains a **ListView** control, where the **Items­Source** property is bound to the **Students** property on the **Student­Collection** class. The list contains five students. However, the presen­tation of the students in the list view is not optimal. |
| **Steps** | 1. Try to improve the presentation of **Student** objects in the list view, by providing an implementation of **ToString** in the **Student** class. 2. Improve the presentation further by defining a data template for the **Student** class (Tip: you can probably use the properties in the **Student** class for this purpose). |

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| **Exercise** | GUI.1.5 |
| **Project** | ExamAdmV15 |
| **Purpose** | Create a Master/Details view |
| **Description** | The application main view again contains a **ListView** control, where the **Items­Source** property is bound to the **Students** property on the **Student­Collection** class. The list contains five students, and a reason­able data template has been provided for presentation. The **Student** class has however been extended with several additional properties. |
| **Steps** | 1. Create the Details part of a Master/Details view (the **ListView** is the Mas­ter part), such that all details of a given **Student** object are shown in the Details part. The Details part should show the details of the **Student** which is currently selected in the list view. (Tip: use the example in the notes for inspiration). 2. Use the styles **TextBlockStyle** and **TextBoxStyle** to specify the appearance of the Details part. |

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| **Exercise** | GUI.1.6 |
| **Project** | ExamAdmV16 |
| **Purpose** | Add deletion functionality to a Master/Details view |
| **Description** | The application contains a working Master/Details view for the **Student** class. We now wish to add functionality to delete a student |
| **Steps** | The steps needed to create deletion functionality are very similar to the steps described in the notes. Almost all changes are done in the **StudentCollection** class. It can be assumed that the **Name** property can be used as a key for **Student** objects.  In the **StudentCollection** class:   1. Change the **\_students** instance field, such that it uses **ObservableCollec­tion** instead of **List** 2. Add a **DoDelete** method, similar to the **DoDelete** method in the notes (it should call the existing **Delete** method) 3. Add a **DoDeleteRelay** method, similar to the **DoDeleteRelay** method in the notes 4. Add a **StudentIsSelected** method, similar to the **CarIsSelected** method in the notes 5. Add a **\_deleteCommand** instance field, of type **RelayCommand** 6. Initialise the **\_deleteCommand** instance field in the constructor, using **DoDeleteRelay** and **StudentIsSelected** as parameters 7. Add a **DeletionCommand** property, similar to the **Deletion­Command** property in the notes 8. Update the **set** part of the **SelectedStudent** property, such that it calls \_**deleteCommand.RaiseCanExecuteChanged**()   In the **MainPage.xaml** file:   1. Add a **Delete** button in a proper place in the view, and bind its **Command** property to **DeletionCommand** 2. Check that you can now delete students from the view! |

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| **Exercise** | GUI.1.7 |
| **Project** | ExamAdmV17 |
| **Purpose** | Consider how insertion/editing functionality can be added to the application |
| **Description** | The application contains a working Master/Details view for the **Student** class, with deletion functionality. A natural extension of the application could be to add functionality for editing existing students, and adding new students |
| **Steps** | 1. Consider what it would take in order to add insertion and editing function­ality to the view. Consider for instance:    * How can we enable editing of specific fields?    * Should all fields be editable?    * Should editable fields be editable all the time?    * How can we manage the “editability” of fields in the Details view?    * What are the detailed steps needed in order to create a new student?    * What sort of validation will be needed when creating a new student (remember we assume that student names are unique)? 2. If you are up to the challenge, feel free to start on the actual implemen­tation of the functionality 3. Finally, consider if the **Student** and **StudentCollection** classes are appro­priate classes for containing all this functionality. Can you envision a better distribution of the functionality? |

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| **Exercise** | GUI.1.8 |
| **Project** | ExamAdmV18 |
| **Purpose** | Save the day at StudentSoft A/S (see memo below) |
| **Description** | **MEMO**: Finish the Show/Hide details feature in the Student view  **From**: Maurice Fischer (StudentSoft A/S CTO)  **TO**: EASJ Intern (can’t remember the name…)  Hi,  Unfortunately, our main developer on the Exam Administration application died yesterday, due to an unfortunate incident involving a hamster, three small oranges and a large piece of brown cardboard. We would therefore like you to finish up the Show/Hide Details feature he was working on in the Students view. I think it was something about being able to toggle the visibility of parts of the Details view on and off, using a Toggle­Switch or something… Anyway, you can probably figure it out by looking in the C# project, as he said he was “almost done” with it, and he always puts…uhh, used to put comments in the code. I would like a demo of it later today, as we are shipping a new version of the application tomorrow.  Regards,  M. Fischer |
| **Steps** | Do as you’re told… |

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| **Exercise** | GUI.2.0 |
| **Project** | ExamAdmV20 |
| **Purpose** | Change the given application from a Model-View (MV) architecture to a Model-View-ViewModel (MVVM) architecture. |
| **Description** | The project initially contains a class **Student**, which acts both as a domain class and a “provider” to the main view (via data bindings in MainPage.xaml). |
| **Steps** | Add a new class **StudentViewModel** to the project, which will acts a the ViewModel in an MVVM architecture. This involves:   1. Create the class **StudentViewModel**. 2. Add an instance field **\_domainObject** of type **Student** to **StudentView­Model**, and initialise it to refer to a new **Student** object in the constructor. 3. Let **StudentViewModel** inherit from **INotifyPropertyChanged**, and generate the code needed (Tip: click the lightbulb ☺). If the includes are not generated automatically, add to the top of the file:   using System.ComponentModel;  using System.Runtime.CompilerServices;   1. Add properties **Name**, **Subject** and **Score** to **StudentView­Model**, in the style described in the notes. 2. Clean up the **Student** class, such that it no longer inherits from **INotifyPropertyChanged** 3. Change the data context in **MainPage.xaml**, and check that the new bindings work as expected. 4. Now create a new property **TopLineText** in **StudentView­Model**, of type **string**. The intention is that this property should provide enough information to enable you to delete the six **TextBlocks** in the top line of the GUI, and replace them with a single **TextBlock**, that binds to **TopLineText**. 5. Delete the six **TextBlocks**, replace them with a single **TextBlock**, and bind the new **TextBlock** to **TopLineText**. Are changes to the data reflected in the top text line? 6. Add extra calls of **OnPropertyChanged** to the **Name**, **Subject** and **Score** properties, in the style described in the notes. Check that changes are now reflected in the top text line |

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| **Exercise** | GUI.2.1 |
| **Project** | ExamAdmV21 |
| **Purpose** | Add and use view model classes in an application |
| **Description** | The given application provides simple read-only functionality for a collection of students (only the Master part of a Master/Details view). For now, the class **StudentItemViewModel** is not used. |
| **Steps** | 1. Add a new class **StudentMasterViewModel** to the project. The intention is that MainPage.xaml should use this class as its new data context. 2. Add two instance fields to the new class:    * **\_studentCollection** of type **StudentCollection**    * **\_****studentItemViewModelCollection** of type **ObservableCollection<StudentItemViewModel>** 3. Initialise the two instance fields in the constructor, by setting them to refer to a new object of each type. 4. Still in the constructor, add **StudentItemViewModel** objects to **\_studentItemViewModelCollection**, by looping through the list of **Student** objects in the collection (Hint: use the **Students** property in the **StudentCollection** class), and create a new **StudentItemViewModel** object for each **Student** object. 5. Add a property**StudentItemViewModelCollection** to **Student­Master­View­Model**. Only the **get**-part of the property is needed; it should just return **\_studentItemViewModelCollection**. 6. Change the data context in MainPage.xaml to use **Student­Master­ViewModel** instead of **StudentCollection**, and change the binding of the **ListView** property **ItemsSource** from **Students** to **StudentItemViewModelCollection**. 7. Rebuild the application, and check that the data is still shown properly when running the application. 8. Do these changes enable you to clean out any properties from **Student** and **StudentCollection**, that were only there to supply GUI-specific data? |

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| **Exercise** | GUI.2.2 |
| **Project** | ExamAdmV22 |
| **Purpose** | Add deletion functionality to a working read-only Master view. |
| **Description** | The application contains a functional read-only Master view, where students can be viewed. The application uses the MVVM architecture. We now want to add deletion functionality to the application |
| **Steps** | In the **StudentMasterDetailsViewModel** class:   1. Add a new property **DeletionCommand** (only the **get**-part is needed) of type **ICommand**, that returns **\_deleteCommand**. 2. Implement a **CanDelete** method, that returns a **bool**. The method should return **true** when it is meaningful to execute the deletion functionality (Hint: A student should probably be selected in the view). 3. Implement a **DoDelete** method, that deletes the selected student, using the name of the student as key (Hint: Use the already implemented **Delete** method ). 4. With **CanDelete** and **DoDelete** implemented, now make a proper initialisation of the **\_deleteCommand** instance field (Hint: Use the **RelayCommand** class, using **DoDelete** and **CanDelete** as parameters).   In MainPage.xaml   1. Add a ***Delete*** button just after the **ListView** control, and bind its **Command** property to **DeletionCommand** 2. Build and run the application. Does the ***Delete*** button work as it should (probably not…)   Back in the **StudentMasterDetailsViewModel** class:   1. In the **set**-part of the **Student­Item­ViewModelSelected** property, add a call of **RaiseCanExecuteChanged** on the \_**deleteCommand** instance field, just before the call of **OnProper­ty­Changed**. 2. Build and run the application again. Does the ***Delete*** button now work as it should (Hopefully it does ☺) |

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| **Exercise** | GUI.2.3 |
| **Project** | ExamAdmV23 |
| **Purpose** | Rewrite domain-specific classes to use provided base classes |
| **Description** | The project contains a working Master view with delete function­a­li­ty. All domain-specific classes are located in the folder **DomainClasses**.  A number of base classes are available in the folder **BaseClasses**, but are not used yet. |
| **Steps** | 1. Let the **Student** class inherit from **DomainClassBase<string>**. This will require that you override the **get**-part of the property **Key**. The property should just return **\_name** (name acts as key for a **Student** object). 2. Let the **StudentModel** class inherit from **ModelBase<Student, string>**. You can then delete everything else from the **StudentModel** class except the constructor. In the constructor, change the calls of **\_students.Add** to use the base class method **Add**. 3. Let the **StudentItemViewModel** class inherit from **ItemViewModel­Base<Student>**. The constructor must then call the base class constructor with **obj** as parameter. Also delete the instance field **\_domainObject**, and replace the use of **\_domainObject** with **DomainObject** in the properties. 4. Let the **StudentMasterViewModel** class inherit from **MasterViewModel­Base<Student, string>**. You can then delete the method **GetStudentItem­View­ModelCollection** from the class. 5. Open the **StudentViewModelFactory.cs** file, and uncomment the class **StudentViewModelFactory**. (tip: select all of the code, and press Ctrl+K+U) 6. Let the **StudentMasterDetailsViewModel** class inherit from **MasterDetails­ViewModelBase<Student, string>**. Then delete everything (yes, everything) from the class… 7. Implement the constructor for **StudentMasterDetailsViewModel** like this**:**   public StudentMasterDetailsViewModel()  : base(new StudentViewModelFactory(), new StudentModel())  {}   1. In **MainPage.xaml**, change the binding of **ItemsSource** to **ItemView­ModelCollection**, and the binding of **SelectedItem** to **ItemViewModel­Selected** 2. Make sure all files are saved, then build and run the application |

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| **Exercise** | PARA.1 |
| **Project** | GenericsDogsAndCircles |
| **Purpose** | Increase cohesion and decrease coupling in the given project, by adding a type-parameterised class |
| **Description** | The project contains two unrelated domain classes **Dog** and **Circle**. The project also contains the class **ObjectComparer**, which contains methods for finding the “largest” **Dog** and **Circle** object out of three given objects. |
| **Steps** | 1. Examine the three given classes, with particular focus on the **ObjectCom­parer** class. What are the problems with this class? 2. Let **Dog** inherit from **IComparable<Dog>** and implement the **CompareTo** method, as described in the notes. Compare according to **Weight**. 3. Let **Circle** inherit from **IComparable<Circle>** and implement the **Compare­To** method, as described in the notes. Compare according to **Area**. 4. Add a new class **BetterObjectComparer** to the project. The class should take one type parameter **T**, and have the constraint **where T : IComparable<T>** 5. Implement a method **Largest**, that takes three parameters of type **T**, and returns a reference to the “largest” object (hint: use the **Compare­To** method). 6. Rewrite the test code in **Program.cs** to use the new **Better­Object­Compa­rer** class. Test that your new code works as expected. 7. Why does this approach decrease coupling? Is there any coupling left between **BetterObjectComparer** and the domain classes? |

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| **Exercise** | PARA.2 |
| **Project** | GenericsDogsAndCircles (same project as used in ***Generics.1***) |
| **Purpose** | Achieve further decoupling by using the **IComparer<T>** interface. |
| **Description** | The project starts out just as ***Generics.1***, with two domain classes **Dog** and **Circle**, and the **ObjectComparer** class. |
| **Steps** | 1. Implement a class **DogCompareByHeight**, which inherits from **IComparer<Dog>**. Implement the **Compare** method as outlined in the notes, and compare dogs by **Height**. 2. Implement a class **CircleCompareByX**, which inherits from **IComparer<Circle>**. Implement the **Compare** method as outlined in the notes, and compare circles by **X** (x-coordinate). 3. Add a new class **EvenBetterObjectComparer** to the project. Note that the class does not need any type parameters. 4. In the **EvenBetterObjectComparer** class, implement a method **Largest<T>** (i.e. a method which takes a type parameter), which takes three para­meters of type **T** and one parameter of type **IComparer<T>**. The method should return a reference to the “largest” object (hint: use the **Compare** method, which is available on the parameter of type **IComparer<T>**). 5. Rewrite the test code in **Program.cs** to use the new **EvenBetter­Object­Comparer** class. Test that your new code works as expected. 6. What are the advantages of this solution, compared to the **BetterObject­Comparer** used in the previous exercise (Hint: Does **Dog** and **Circle** need to implement any interfaces now)? |

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| **Exercise** | PARA.3 |
| **Project** | GenericsVariance |
| **Purpose** | Illustrate practical benefits from declaring type parameters as co-variant or contra-variant |
| **Description** | The project contains a simple class system for animals: An **Animal** base class, and two derived classes **Bird** and **Cat**. Furthermore, the project contains interfaces and classes for collections and collection processing. |
| **Steps** | 1. Examine the two interfaces **ICollectionGet<T>** and **ICollectionSet<T>**. Pay particular attention to how the type parameter **T** is used in each interface. 2. Examine the class **Collection<T>**. It is a very simple collection class, that implements the two interfaces mentioned above. 3. Examine the **AnimalProcessor** class, which contains four methods. Pay particular attention to the type of the parameter to each method, and to the operations performed inside the methods. 4. Now open **Program.cs**, and examine the code. Notice the commented-out code, which contains 8 method calls (Case A to H). Before un-commenting the code, see if you can work out which method calls are valid, and which are not (Hint: Pay close attention to the specific type of the parameter in each call). 5. Un-comment the code. How many cases did you get right? 6. Now open the **ICollectionGet<T>** interface. Declare the type parameter **T** to be co-variant, by adding the keyword **out** just before the **T**, like this: **ICollectionGet<out T>**. 7. Go back to **Program.cs**. Which case(s) that were previously invalid are now valid? See if you understand why… 8. Now open the **ICollectionSet<T>** interface. Declare the type parameter **T** to be contra-variant, by adding the keyword **in** just before the **T**, like this: **ICollectionSet<in T>**. 9. Go back to **Program.cs**. Which case(s) that were previously invalid are now valid? See if you understand why… 10. Two cases remain invalid. Do you think we in any way could fix this by further adjustments of the interfaces? 11. Since the **Collection** class implements both **ICollectionGet<T>** and **ICollectionSet<T>**, wouldn’t it be easier just to have a single interface **ICollection<T>**, containing all methods from the two interfaces? What would the consequences be? |

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| **Exercise** | PARA.4 |
| **Project** | LambdaAnimals |
| **Purpose** | Write a couple of small lambda expressions. Filter a collection using a lambda expression. |
| **Description** | The project contains a single class **Animal**, which has two instance fields of type **Func<string>**, i.e. a function which:   * Has no parameters * Returns a value of type **string** |
| **Steps** | 1. Study the class **Animal**. In particular, note that the constructor takes two parameters of type **Func<string>**. 2. In **Program.cs**, create some **Animal** objects. You will need to write a couple of small lambda expressions, in order to be able to create an **Animal** object. 3. Once you have created the objects, also create a **List<Animal>**, and insert the **Animal** objects into the list. 4. Create a **foreach**-loop that prints out the **Animal** objects in the list. Since **ToString** has been implemented in the **Animal** class, you can just use **Animal** objects as parameters to **Console.WriteLine** directly. 5. Now update the **foreach**-loop in the following way: Instead of having a loop take looks like:   foreach (var animal in animals) {…}    it should now look like:  foreach (var animal in animals.FindAll(…) {…}  Define a selection criterion – in the form of a lambda expression – and use it as a parameter to **FindAll**. You could e.g. select those **Animal** objects that are of a certain type, or make a speci­fic sound, or a combination.   1. Consider pros and cons of this approach:    1. Is this a sensible way of defining a class with two string properties?    2. Is this a sensible alternative to Inheritance? Consider for instance how we would represent “sub-classes” like **Dog** and **Cat**, and how we would be able to use **FindAll** for finding e.g. all **Cat** objects in an **Animal** list? |

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| **Exercise** | PARA.5 |
| **Project** | ClockV20 |
| **Purpose** | Use events to connect two domain objects. |
| **Description** | The project contains two classes:  **PulseGenerator**: This class can generate an event at regu­lar time intervals, and allow other objects to be notified of these events.  **Clock**: This class simulates a simple 24-hour clock |
| **Steps** | 1. Study the **PulseGenerator** class. Note in particular the **Pulse** event. What methods (with regards to parameters and return values) can be attached to this event? 2. Study the **Clock** class. Note in particular the methods **Tick** and **PrintTime**. How do you think they will be related to the **Pulse** event? 3. In **Program.cs**, a **PulseGenerator** object is created. Further down, the method call **theGenerator.Start(1000)** is invoked. Between those two lines, create a **Clock** object, e.g. with a Danish text. 4. Just after creating the **Clock** object, attach the relevant methods from the object to the **Pulse** event on the **PulseGenerator** object. 5. Start the application, and see if the clock progresses as expected. 6. Create some additional **Clock** objects with different texts – and perhaps different tick factors – and attach them to the **Pulse** event. 7. Start the application again, and see if the additional clock objects behave as expected. |

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| **Exercise** | PARA.6 |
| **Project** | StockTrade |
| **Purpose** | Use events to connect various domain objects. |
| **Description** | The project contains classes for (very simplified) simulation of stock trading. Some objects will generate events, while other objects will need to be notified of these events. |
| **Steps** | 1. Study the **TradeLog** class – it is quite simple ☺. 2. Study the **PulseGenerator** class. This class can generate an event at regu­lar time intervals, and allow other objects to be notified of these events. 3. Study the **Stock** class. It simulates a real stock, including price changes. Notice the method **GenerateNewPrice**. Who do you think should call this method? Also notice the event **PriceChanged**. What is it used for? 4. Study the class **StockTrader**. It simulates a real stock trader, in a very simplified way. Note the method **DoTrade**. How is this method related to the **PriceChanged** event in the **Stock** class?   We now want to connect the pieces to create a stock trade simulation. This is done in **Program.cs**.   1. After the creation of the **PulseGenerator** object – but before the call of **thePulseGenerator.Start** – create a few **Stock** objects. Choose some reasonable upper and lower limits for stock prices. 2. Create some **StockTrader** objects. Each stock should be traded by at least one stock trader. 3. Make sure that the **Stock** objects have their **GenerateNewPrice** method called, whenever the **PulseGenerator** object generates a **Pulse** event. 4. Make sure that the **StockTrader** objects are notified about changes in stock prices for the relevant stocks. 5. On each **Pulse** event, print out the current price of all stocks (hint: Create a lambda expression which prints out the stock prices, and attach it to the **Pulse** event). 6. On the **LastPulse** event, print out the entire trade log. 7. Run the application. Check to see if the trades obey the limits set for each stock trader. 8. See if you can extend the stock trader model, maybe by letting each stock trader trade more than one stock, have more advanced criteria for buying or selling, etc.. |

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| **Exercise** | PRO.3.1 |
| **Project** | DataStructureCompare |
| **Purpose** | Observe a comparative test of three collection classes, when exposed to various types of use. |
| **Description** | The project contains classes that enable you to measure the perform­ance (in terms of run-time) of various operations, when performed on various collection classes. |
| **Steps** | 1. The class **TimedTester** is a general class for measuring the run-time of a method invocation. Have a look at the class, and notice the very useful class **Stopwatch** from the .NET library. 2. The interface **IDataStructureTester** and the class **DataStructureTesterBase** are general-purpose classes for collection class test. Study the classes, until you feel you understand the general structure of the test. 3. The classes **ListTester**, **LinkedListTester** and **HashSetTester** contain the specific test for each collection class. Compare how the test is done for each class, i.e. how are the **…Statement** methods implemented for each collection class. 4. **Program.cs** contains the code which executes the test. Get an overview of the test, and try to run the application. 5. Given the discussion about pros and cons of the various collection classes, do the actual run-times reported by the tests make sense? Or are there any surprising results? Note that it is not the absolute run-times that are of interest here – it is the relative measurements of performing the same operation of different collection classes, or different operations on the same collection class. 6. Try to increase the value of **noOfInserts**, in order to increase the number of times the various operations are invoked. What are your expectations to the running time of the various operations, if you e.g. double the value of **noOfInserts**? Do the results match your expectations? If not, try to think about plausible reasons for this. |

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| **Exercise** | PRO.3.2 |
| **Project** | Palindrome |
| **Purpose** | Solve a simple problem using a recursive approach |
| **Description** | A **palindrome** is a phrase that reads the same backwards and forwards, like “Racecar” or “Amore Roma”. Note that spaces and upper/lowercase is ignored in this definition.  The **Palindrome** project contains an interface **IPalindromeChecker** and a class **PalindromeChecker**. |
| **Steps** | 1. Study the interface **IPalindromeChecker** and the class **Palin­drome­Checker**. They are both quite simple. 2. In **Program.cs**, some test code has been provided. The test code makes it easy to check if your palindrome checker works properly. Try to run the application, and see the results. 3. In **PalindromeChecker**, the method **IsPalindromeInternal** is not imple­men­ted properly. Implement a better version, using a recursive approach.    1. Think about how you can divide the original problem into two small­er problems, and also about when the problem is trivially solved.    2. You will probably need to use the method **Substring**, which can be called on variables of type **string**.    3. Once you think the implementation is correct, you can just run the application again, and study the test output. |

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| **Exercise** | PRO.3.3 |
| **Project** | BackPacking |
| **Purpose** | Solve a real-life problem using a recursive approach |
| **Description** | The project contains several classes to support solving of the so-called **Backpacking** problem:  Given   * A **backpack** with limited weight capacity * A set of **items**, each with a weight and a value   Select a set of items from the given items, such that:   * The items can fit into the backpack * The items have as high a total value as possible. |
| **Steps** | 1. Study the single class **BackPackItem** in the **Item** folder. It should be fairly straightforward. 2. Study the classes in the **Containers** folder (start with **BackPackItem­Container**), until you understand their purpose and functionality. 3. Study the classes in the **Algorithms** folder (start with I**BackPackingSolver**), until you understand their purpose and functionality. 4. Study the code in **Program.cs** – it uses the “stupid” solver to solve a specific backpacking problem. 5. Run the program, and study the output. Are there some obvious indica­tions that the algorithm does not produce the best possible result? 6. Now create a new class **BackPackingSolverSmart**, which should inherit from **BackPackingSolverBase**. Implement a smarter version of **Solve**, i.e. an algorithm which is smarter than the one found in **BackPackingSolver­Stupid**. Hints:    1. Think about a better way to select the next item to put into the backpack.    2. Try to think recursively. |

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| **Exercise** | PRO.3.4 |
| **Project** | LINQDrink |
| **Purpose** | Use LINQ queries on a single collection of objects |
| **Description** | The project contains a **Drink** class, which is fairly straightforward. In **Program.cs**, a **List** of **Drink** objects is created. |
| **Steps** | For each of the below cases, write a LINQ query that returns the speci­fied result, and print out the result of the query, using a **foreach**-loop:   1. The names of all drinks. 2. The names of all drinks without alcohol. 3. The name, alcohol part and alcohol amount for all drinks with alcohol. 4. The names of all drinks in alphabetical order. 5. The total amount of alcohol in the drinks. 6. The average amount of alcohol in drinks with alcohol. 7. The name and alcohol amount of each drink, grouped by alcohol part (NB: We have not discussed grouping in class! Seek information about the **group** LINQ operator online in order to solve this case ☺) |

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| **Exercise** | PRO.3.5 |
| **Project** | LINQCocktails |
| **Purpose** | Use LINQ queries – including **join** – on two collections of objects |
| **Description** | The project contains an **Ingredient** class and a **Cocktail** class. A **Cock­tail** object contains a collection of **Ingredient** objects. In **Program.cs**, a **List** of **Ingredient** objects and a **List** of **Cocktail** objects are created. |
| **Steps** | For each of the below cases, write a LINQ query that returns the speci­fied result, and print out the result of the query (NB: Note that some queries will return collec­tions of collections, so you may need a nest­ed loop to print the query result properly).   1. The names of all cocktails. 2. For each cocktail: The name, and all ingredients 3. For each cocktail: The name, and name of all ingredients with an alcohol percentage above 10 % 4. For each cocktail: The name, and the price of the cocktail (note that the price (per cl.) for an ingredient can be found in the **Ingredient** object collection). 5. For each cocktail: The name, and the alcohol percentage of the cocktail. 6. The ingredients in a **Cocktail** object are referred to by the name of the ingredient, through the **\_ingredients** dictionary. An alternative strategy could be to refer directly to **Ingredient** objects, i.e. change the type of the dictionary to <**Ingredient**, **int**>. Make this change – this will also require updates to the code in **program.cs**. What effect does this change have on the LINQ queries you wrote previously? |

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| **Exercise** | PRO.3.6 |
| **Project** | CrossTalk |
| **Purpose** | See how the **Task** class can be used to execute some very simple operations in parallel |
| **Description** | The project contains the class **Reciter**, which contains a couple of fairly simple methods. The method **ReciteAllTheWords** executes a recitement of the numbers 1 to 8, in three different languages. Each recitement is done by calling the method **Recite**. |
| **Steps** | 1. Run the application. You will see that the recitements are done sequen­tially, i.e. one recitement is completed before the next recitement is executed. 2. Change the code in the **ReciteAllTheWords** method, such that the recitements are done in parallel. The effect should be that the printouts on the screen are a mix of the three languages (Hint: each recitement should be turned into a task). 3. A side-effect of the changes made in step 2 is that the message *"Press any key to close application"* is now printed long before the last word is printed. Why does this happen? |

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| **Exercise** | PRO.3.7 |
| **Project** | NumericalPi |
| **Purpose** | Change the execution of a time-consuming calculation to use **Tasks**, to decrease the absolute running time. |
| **Description** | The project contains the class **PiCalc**, which contains an algorithm for calculating an approximate value of π (the exact value of π can be retrieved from **Math.PI**).  The method **Iterate** will do this for the specified number of iterations:   * Generate a random point within the square [0;1[ x [0;1[ (a.k.a. the unit square) * Count the number of times the point falls within the circle with center at (0,0), and radius 1 (a.k.a. the unit circle).   The ratio between the parameter **iterations** and the returned number (**inside­Unit­Circle**) will approximate π/4. The higher the number of iterations, the closer the ratio will come to π/4. The final estimate is then easy to calculate, as is done in the **Calculate** method.  Suppose you had to do this calculation manually. You could e.g. draw the square and circle on a piece of paper, and throw a dart at the paper e.g. 100 times. You should then count the number of times the dart has hit within the circle. Say the dart hit within the circle 77 times. Your estimate of π would then be (4.0 \* 77) / 100 = 3.08. |
| **Steps** | 1. You invite three friends over to help with your experiment. A total of four persons can now throw darts. How will you utilise this to speed up the experiment? 2. See if you can translate your redesigned experiment into a new version of **Calculate**, where you use **Task** objects (Hint: wrap the code corresponding to what one person should do, into a **Task** object, like **Task task1 = Task.Run( () => {…});**) 3. Compare the running time of your new version of **Calculate** with the original version. How much faster is your version? 4. See if you can figure out how many cores your CPU has. How does this number relate to what you observed in step 3? |

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| **Exercise** | PRO.3.8 |
| **Project** | SlicesOfPi |
| **Purpose** | See the usefulness of using the **async**/**await** programming model |
| **Description** | In PRO.3.6, we saw a an algorithm for calculating an approximate value of π. The algorithm is fairly easy to speed up using tasks, but it still has to run to completion, before a value is available. It could be useful to – at any time during the calculation – be able to:   * See how good the currently calculated value of π is. * Stop the calculation, and use to current value as the final result.   The project contains two approaches to solving this.   * A synchronous approach (I,e, no use of tasks or async/await), where the user can request that small “slices” of the calculation are done. A calculation slice can not be interrupted. After each slice, the user can choose to accept the calculated value, or perform additional slices. * An asynchronous approach, where the main calculation loop is wrapped into a task, which is awaited. This makes it possible to interrupt the calculation at any time. |
| **Steps** | 1. Study the class **PiCalcData** in the project. It holds a bit of data related to the calculation, and is fairly simple. 2. Study the method **Calculate** in the class **PiCalcAlgorithm**. It uses a tradi­tional, sequential style and cannot be interrupted. 3. Study the methods **RunPiCalculation** and **MainUILoop** in the class **PiCalc­UI**. They manage the user interaction for the synchronous approach. Note how the **MainUILoop** method calls **Calculate**, with the number of itera­tions specified by the user. 4. Try to run the application (make sure that **RunPiCalculation** is called in **Main**). How do you feel about this way of interaction? Try to enter a large (VERY large, like 100,000,000) number of iterations. Can you interact with the application during the calculation? 5. Now study the methods **RunPiCalculationAsync** and **MainUILoopForAsync** in the class **PiCalc­UI**. They manage the user interaction for the asynchron­ous approach. In particular, note how the **RunPiCalculationAsync** method calls **CalculateAsync**. That call returns a **Task<double>** object; where is that object awaited? What happens just before that object is awaited? 6. Try to run the application, using **RunPiCalculationAsync** in **Program.cs** instead. How has the interaction changed, compared to step 4? Can you now interact with the application while the calculation is ongoing? |

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| **Exercise** | PRO.3.9 |
| **Project** | ProducerConsumer |
| **Purpose** | Work with a typical producer/consumer setup, involving Tasks and data locking |
| **Description** | The project contains several classes, which participate in a so-called **producer/consumer** scenario. A “producer” produces objects and inserts them into a data structure, while a “consumer” consumes objects by removing them from the same data structure. The production and consumption should be executed in parallel |
| **Steps** | 1. Study all of the classes in the project. Note that this a a fairly large project, and some of the classes are a bit complex, so be prepared to spend some time on this steps. 2. Team up with another student, and discuss your understanding of the overall application, and the individual classes. If you disagree on something, you must investigate the code further. 3. Try to run the application as-is. You will see that the reporting looks strange (sort of jumps up and down a bit on the screen). Why do you suppose this happens? Try to fix the problem (Hint: Maybe only one thread should try to print on the screen at any time…) 4. Try to change the reporting mode (last parameter in the **Scenario** constructor) to **ReportMode.silent**, and re-run the application. Why is the message *"Press any key to abort the run..."* printed almost immediately after starting the app? 5. The above run probably gave the result that all balances were good. Try to change the first five parameters to the **Scenario** constructor to 1000, 500, 1000, 3, 2. Re-run the app. Do you see any bad balances now? Try to run the app a few times. Do the results change from run to run? 6. See if you can figure out how to get rid of the bad balances problem (Hint: What data can be accessed by both the producer and consumer?). 7. See if you can extend the application to include several producers and/or consumers. |

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| **Exercise** | PRO.3.10 |
| **Project** | TestExampleA |
| **Purpose** | Implement a method, using existing unit tests as guidance. |
| **Description** | The solution contains two projects:  The project **TestExampleA** con­tains the class **ListMethods**, with the single method **SumOfSquaresOf­Positives**.  The project **UnitTestProject** contains the class **ListMethods­UnitTest**, which contains test cases for testing the method **SumOfSquaresOf­Positives**. |
| **Steps** | 1. Study the **SumOfSquaresOf­Positives** method. The method itself is initially empty, so focus on understanding what the method should do. This is described in the comments. 2. Study the test cases in **ListMethods­UnitTest**. Try to run the tests (open the **Test Explorer** window, by choosing **Test** | **Windows** | **Test Explorer**, and click **Run All** in the **Test Explorer** window). Note that some of the tests actually pass, even though the method is clearly not correctly implemen­ted yet. 3. Implement **SumOfSquaresOf­Positives** correctly, such that all test cases pass. 4. Do you find the existing test cases to be sufficient? Can you think of some test cases it would be useful to add? |

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| **Exercise** | PRO.3.11 |
| **Project** | TestExampleB |
| **Purpose** | Implement a unit test for an existing class. |
| **Description** | The solution contains two projects:  The project **TestExampleB** con­tains the class **Warrior**.  The project **UnitTestProject** contains the class **Warrior­UnitTest**, which should contain test cases for testing the **Warrior** class. Initially, the unit test only contains a few test cases, and needs to be extended. |
| **Steps** | 1. Study the **Warrior** class, until you have a detailed understan­ding of how it is intended to work. 2. Study the existing test cases in **Warrior­UnitTest**. They are clearly insuffi­cient… 3. Add new test cases to **Warrior­UnitTest**, until you feel you have covered all aspects of the functionality. You can use the existing test cases for inspira­tion, with regards to how to struc­ture test cases. |

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| **Exercise** | PRO.3.12 |
| **Project** | TestExampleC |
| **Purpose** | Implement both a class and associated unit test, given a requirement specification |
| **Description** | The solution contains two projects:   * The project **TestExampleC** con­tains the class **Currency­Exchange**. * The project **UnitTestProject** contains the class **Currency­Exchange­Test**.   None of the classes are complete, however. The starting point is the below requirement specification (see next page), from which the **CurrencyExchange** class and the **CurrencyExchangeTest** class must be completed. |
| **Steps** | 1. Implement the **CurrencyExchange** class and the **Currency­Exchange­Test** class, given the below requirement specification. If you are in doubt about a specific requirement detail, you must make a decision about how to interpret it, and work forward from that. 2. When you are done with the requirements specified below, you can try to extend the class (and the test class) along these lines:  * If the currency cross **AAABBB** is specified, you can calculate exchanges from **AAA** to **BBB**. However, that should also make it possible to calcu­late exchanges from **BBB** to **AAA**. * Suppose you wish to make an exchange from **AAA** to **CCC**. This curren­cy cross has not been specified, but **AAABBB** and **BBBCCC** have. This can be utilised to calculate the **AAACCC** exchange rate. * Exchange rates should be consistent. If you have specified **AAABBB** = 2 and **BBBCCC** = 3, it should not be possible to set **AAACCC** to e.g. 7 (it should be 6). |

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| **Exercise** | PRO.3.12 (continued) |
| **Requirement**  **Specification** | **CurrencyExchange – Definitions**   * A **currency identifier** is defined as being a three-character acronym for a currency. Examples are **USD** (US Dollars), **EUR** (Euro), **DKK** (Danish Kroner), and so on. * A **currency cross** is a combination of two different currency identifiers. Examples are **EURUSD** (Euro to US Dollars), **DKKEUR** (Danish Kroner to Euro), and so on. * An **exchange rate** is a currency cross and a positive decimal number. Example: (**EURUSD**, 1.20), meaning that 1.00 Euro is worth 1.20 US Dollar.   **CurrencyExchange – Requirement specifications**   * It must be possible to specify a number of exchange rates. * Trying to specify an illegal exchange rate (see Definitions), should cause an exception to be thrown. * It is permitted to change an existing exchange rate, simply by specifying it again. * Given a currency cross **AAABBB** and a positive amount of currency **AAA**, it must be possible to calculate the amount obtained by exchanging the amount to currency **BBB**. Example: Given **USDDKK** = 6.50 and an amount of 200 **USD**, the result should be 1300 **DKK**. * Trying to perform the calcuation with either an illegal (or non-existing) currency cross or illegal amount, should cause an exception to be thrown. |

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| **Exercise** | DAPE.1 |
| **Project** | NoteBookV10 |
| **Purpose** | Add Load- and Save-functionality to an MVVM application |
| **Description** | The given application contains a very simple system for creating notes. A note consists of a title and some content. It is not allowed to have two notes with the same title. However, the application does not support saving and loading of notes yet. |
| **Steps** | In the **NoteMasterDetailsViewModel** class:   1. Add a new instance field **\_loadCommand**, of type **Relay­Command** 2. Add a new property **LoadCommand**, of type **ICommand**. It should just return the instance field **\_loadCommand**, in the same style as e.g. the **AddCommand** property. 3. Add a new method **Load**, in the same style as in the notes. That is, it should call **Load** on the **\_model** instance field. 4. In the constructor, initialise **\_loadCommand** in the same style as in the notes. 5. In the method **NotifyCommands**, add a call of **RaiseCanExecuteChanged** on the **\_loadCommand** instance field 6. Repeat steps 1-5 for the Save functionality   In the **MainPage.xaml** file:   1. Add two new buttons **Load** and **Save** to the view, and bind them to the **LoadCommand** and **SaveCommand** property, respectively. 2. Rebuild the application, and see if you can now load and save notes. Create some notes, click **Save**, close the application, start it again, click **Load**, and see if the saved notes reappear. |

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| **Exercise** | DAPE.2 |
| **Project** | NoteBookV20 |
| **Purpose** | Use exceptions for error-handling in an MVVM application |
| **Description** | The given application checks that notes cannot have the same title (try it!), but the implementation is quite a mess… The handling is all done in the **set**-part of the **Title** property in **NoteDetailsViewModel**, with several calls to the model and the master-details view model |
| **Steps** | Our aim is to clean up the error handling. This involves using exceptions for error signaling and handling, and also to distribute various responsibilities to the proper classes. An exception class **TitleExistsException** is included in the project.   1. In the **NoteModel** class, add checks to the methods **Add** and **UpdateTitle**, such that a **TitleExistsException** is thrown if the new title exists 2. In the **NoteMasterDetailsViewModel** class, uncomment the method **UpdateTitle**. See if you understand why the method is structured in this particular way. 3. In the **NoteDetailsViewModel** class, go to the **set**-part of the **Title** property. Remove ALL the code in the **set**-part, and replace it with a single line of code:   \_masterDetailsViewModel.UpdateTitle(value);   1. Clean up the **NoteDetailsViewModel** class a bit, since it no longer needs a reference to the model (remove the instance field, and remove the parameter from the constructor) 2. Rebuild the application and run it. See if the validation of titles still works as before. 3. See if you can answer the below questions:    1. Which class **detects and signals** the error?    2. Which class **assumes responsibility** for handling the error?    3. Which class **reports** the error to the user? 4. If you have more time, see if you can update the application such that the **Title** and **Content** fields in the view are only enabled if the user has selected a Note in the list view. |