

## Esercizio 1

### Expr.java

```
public abstract class Expr {
    public abstract Expr apply (Expr target, double value);

    public AddExpr add (Expr that) { return new AddExpr(this, that); }
    public MulExpr mul (Expr that) { return new MulExpr(this, that); }
    public SubExpr sub (Expr that) { return new SubExpr(this, that); }
}
```

### BinaryExpr.java

```
public abstract class BinaryExpr extends Expr {
    protected BinaryExpr (Expr first, Expr second) {
        this.first = first;
        this.second = second;
    }

    public Expr apply (Expr target, double value) {
        this.first = this.first.apply(target, value);
        this.second = this.second.apply(target, value);
        return this;
    }

    protected Expr first;
    protected Expr second;
}
```

### AddExpr.java

```
public class AddExpr extends BinaryExpr {
    public AddExpr (Expr first, Expr second) { super(first, second); }
}
```

### MulExpr.java

```
public class MulExpr extends BinaryExpr {
    public MulExpr (Expr first, Expr second) { super(first, second); }
}
```

### SubExpr.java

```
public class SubExpr extends BinaryExpr {
    public SubExpr (Expr first, Expr second) { super(first, second); }
}
```

### UnaryExpr.java

```
public abstract class UnaryExpr extends Expr {
    protected UnaryExpr (Expr argument) {
        this.argument = argument;
    }
}
```

```

    }

    public Expr apply (Expr target, double value) {
        this.argument = this.argument.apply(target, value);
        return this;
    }

    protected Expr argument;
}

```

### NegExpr.java

```

public class NegExpr extends UnaryExpr {
    public NegExpr (Expr argument) { super(argument); }
}

```

### ExpExpr.java

```

public class ExpExpr extends UnaryExpr {
    public ExpExpr (Expr argument) { super(argument); }
}

```

### DoubleExpr.java

```

public class DoubleExpr extends Expr {
    public DoubleExpr () {}

    public Expr apply (Expr target, double value) {
        return (target == this) ? new ConstExpr(value) : this;
    }
}

```

### ConstExpr.java

```

public class ConstExpr extends Expr {
    public ConstExpr (double value) {
        this.value = value;
    }

    public Expr apply (Expr target, double value) {
        return this;
    }

    private double value;
}

```

### Function.java

```

public class Function {
    public Function (Expr[] arguments, Expr expression) {
        this.arguments = arguments;
        this.expression = expression;
    }
}

```

```

    }

    public Expr apply (double... values) {
        for (int i = 0; i < values.length; i++)
            this.expression = this.expression.apply(arguments[i], values[i]);

        return this.expression;
    }

    private Expr[] arguments;
    private Expr expression;
}

```

## Esercizio 2

### Expr.java

```

public abstract class Expr {
    // ...

    public abstract String compile ();
}

```

### BinaryExpr.java

```

public abstract class BinaryExpr extends Expr {
    // ...

    public String compile () {
        return "(" + this.first.compile() + this.operator() + this.second.compile() + ")";
    }

    protected abstract String operator ();
}

```

### AddExpr.java

```

public class AddExpr extends BinaryExpr {
    // ...

    protected String operator () { return " + "; }
}

```

### MulExpr.java

```

public class MulExpr extends BinaryExpr {
    // ...

    protected String operator () { return " * "; }
}

```

### SubExpr.java

```
public class SubExpr extends BinaryExpr {
    // ...

    protected String operator () { return " - "; }
}
```

### UnaryExpr.java

```
public abstract class UnaryExpr extends Expr {
    // ...

    public String compile () {
        return this.operator() + "(" + this.argument.compile() + ")";
    }

    protected abstract String operator ();
}
```

### NegExpr.java

```
public class NegExpr extends UnaryExpr {
    // ...

    protected String operator () { return "-"; }
}
```

### ExpExpr.java

```
public class ExpExpr extends UnaryExpr {
    // ...

    protected String operator () { return "exp"; }
}
```

### DoubleExpr.java

```
public class DoubleExpr extends Expr {
    // ...

    public DoubleExpr (String name) {
        this.name = name;
    }

    public String compile () {
        return this.name;
    }

    private String name;
}
```

## ConstExpr.java

```
public class ConstExpr extends Expr {
    // ...

    public String compile () {
        return Double.toString(this.value);
    }
}
```

## Esercizio 3

### Expr.java

```
public abstract class Expr {
    // ...

    public abstract Expr differentiate (Expr dx);
}
```

### AddExpr.java

```
public class AddExpr extends BinaryExpr {
    // ...

    public Expr differentiate (Expr dx) {
        return new AddExpr(this.first.differentiate(dx), this.second.differentiate(dx));
    }
}
```

### MulExpr.java

```
public class MulExpr extends BinaryExpr {
    // ...

    public Expr differentiate (Expr dx) {
        return new AddExpr(
            new MulExpr(this.first.differentiate(dx), this.second),
            new MulExpr(this.first, this.second.differentiate(dx))
        );
    }
}
```

### SubExpr.java

```
public class SubExpr extends BinaryExpr {
    // ...

    public Expr differentiate (Expr dx) {
        return new SubExpr(this.first.differentiate(dx), this.second.differentiate(dx));
    }
}
```

## NegExpr.java

```
public class NegExpr extends UnaryExpr {
    // ...

    public Expr differentiate (Expr dx) {
        return new NegExpr(this.argument.differentiate(dx));
    }
}
```

## ExpExpr.java

```
public class ExpExpr extends UnaryExpr {
    // ...

    public Expr differentiate (Expr dx) {
        return new MulExpr(new ExpExpr(this.argument), this.argument.differentiate(dx));
    }
}
```

## DoubleExpr.java

```
public class DoubleExpr extends Expr {
    // ...

    public Expr differentiate (Expr dx) {
        return (dx == this) ? new ConstExpr(1) : new ConstExpr(0);
    }
}
```

## ConstExpr.java

```
public class ConstExpr extends Expr {
    // ...

    public Expr differentiate (Expr dx) {
        return new ConstExpr(0);
    }
}
```

## Function.java

```
public class Function {
    // ...

    public Function differentiate (Expr dx) {
        return new Function(this.arguments, this.expression.differentiate(dx));
    }
}
```

## Esercizio 4

### Expr.java

```
public abstract class Expr {  
    // ...  
  
    public abstract Expr simplify ();  
    public abstract Expr simplify (UnaryExpr parent);  
    public abstract Expr simplify (BinaryExpr parent, Expr sibling);  
}
```

### BinaryExpr.java

```
public abstract class BinaryExpr extends Expr {  
    // ...  
  
    public Expr simplify () {  
        this.first = this.first.simplify();  
        this.second = this.second.simplify();  
        return this.second.simplify(this, this.first);  
    }  
  
    public Expr simplify (UnaryExpr parent) { return parent; }  
    public Expr simplify (BinaryExpr parent, Expr sibling) { return parent; }  
    public abstract Expr simplify (ConstExpr first, Expr second);  
}
```

### AddExpr.java

```
public class AddExpr extends BinaryExpr {  
    // ...  
  
    public Expr simplify (ConstExpr first, Expr second) {  
        return first.isZero() ? second : this;  
    }  
}
```

### MulExpr.java

```
public class MulExpr extends BinaryExpr {  
    // ...  
  
    public Expr simplify (ConstExpr first, Expr second) {  
        return first.isZero() ? first : this;  
    }  
}
```

### SubExpr.java

```
public class SubExpr extends BinaryExpr {  
    // ...
```

```

        public Expr simplify (ConstExpr first, Expr second) {
            return first.isZero() ? new NegExpr(second) : this;
        }
    }

```

## UnaryExpr.java

```

public abstract class UnaryExpr extends Expr {
    // ...

    public Expr simplify () {
        this.argument = this.argument.simplify();
        return this.argument.simplify(this);
    }

    public Expr simplify (UnaryExpr argument) {
        return this.argument;
    }

    public Expr simplify (BinaryExpr parent, Expr sibling) { return parent; }
}

```

## NegExpr.java

```

public class NegExpr extends UnaryExpr {
    // ...

    public Expr simplify (NegExpr parent) {
        return parent.simplify(this);
    }
}

```

## ExpExpr.java

```

public class ExpExpr extends UnaryExpr {
    // ...

    public Expr simplify (UnaryExpr parent) { return parent; }
}

```

## DoubleExpr.java

```

public class DoubleExpr extends Expr {
    // ...

    public Expr simplify () { return this; }
    public Expr simplify (UnaryExpr parent) { return parent; }
    public Expr simplify (BinaryExpr parent, Expr sibling) { return parent; }
}

```



## ConstExpr.java

```
public class ConstExpr extends Expr {
    // ...

    public Expr simplify () {
        return this;
    }

    public Expr simplify (UnaryExpr parent) {
        return parent;
    }

    public Expr simplify (BinaryExpr parent, Expr sibling) {
        return parent.simplify(this, sibling);
    }

    public boolean isZero () {
        return Math.abs(this.value - 0) < this.EPS;
    }

    private static double EPS = 0.000001;
}
```

## Esercizio 5

### VectorExpr.java

```
import java.util.List;
import java.util.ArrayList;

public class VectorExpr extends Expr {
    public VectorExpr (int dimension) {
        this.dimension = dimension;
        this.elements = new ArrayList<Expr>(dimension);
    }

    public VectorExpr (int dimension, List<Expr> elements) {
        this.dimension = dimension;
        this.elements = elements;
    }

    public VectorExpr apply (Expr target, double value) {
        for (int i = 0; i < this.dimension; i++)
            this.elements.set(i, this.elements.get(i).apply(target, value));

        return this;
    }

    public String compile () {
        String result = "double result[] = { ";
        for (int i = 0; i < this.dimension; i++)
```

```

        result += this.elements.get(i).compile() +
            ((i < this.dimension - 1) ? ", " : " }");

        return result;
    }

    public VectorExpr differentiate (Expr dx) {
        for (int i = 0; i < this.dimension; i++)
            this.elements.set(i, this.elements.get(i).differentiate(dx));

        return this;
    }

    public VectorExpr simplify () {
        for (int i = 0; i < this.dimension; i++)
            this.elements.set(i, this.elements.get(i).simplify());

        return this;
    }

    public Expr simplify (UnaryExpr argument) {
        return this;
    }

    public Expr simplify (BinaryExpr parent, Expr sibling) {
        return this;
    }

    public VectorExpr add (VectorExpr that) {
        List<Expr> newElements = new ArrayList<Expr>(this.dimension);

        for (int i = 0; i < this.dimension; i++)
            newElements.add(i, new AddExpr(this.elements.get(i), that.elements.get(i)));

        return new VectorExpr(this.dimension, newElements);
    }

    protected int dimension;
    protected List<Expr> elements;
}

```

## Esercizio 6