Consider the compilation of the following (miniJava) expression for a register-oriented processor architecture like MIPS (here variables $x$ and $y$ are int variables stored in memory)

$$(x + y) \times x + (x + y)$$

(a) (on back) Show an AST for this expression and use Sethi-Ullman numbering on each node to determine the minimum number of registers needed to evaluate the expression. How many registers are needed?

(b) (on back) Show the tuple code generated by simple code generation using temporaries.

(c) (on back) Show how the tuple code in (b) can be simplified to the code in (d) using common subexpression elimination.

(d) Determine the lifetimes of each temporary $t1$ – $t5$.

```
t1 := x

t2 := y

t3 := t1 + t2

t4 := t3 * t1

t5 := t4 + t3
```

(e) What is the minimum number of registers $k$ needed to evaluate the tuple code above? Show an assignment of temporaries to $k$ registers by constructing the interference graph and coloring it using $k$ colors.