Question 1: Liveness analysis (20 points)

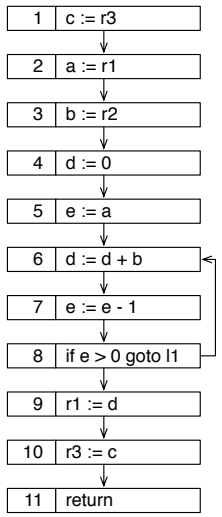
```
        c := r3
        a := r1
        b := r2
        d := 0
        e := a
l1:     d := d + b
        e := e − 1
        if e > 0 goto l1
        r1 := d
        r3 := c
        return
```

(a) Construct the control graph for the intermediate code on the left. (2)

(b) Calculate successor nodes, defined variables, and used variables for each node in the control graph. (3)

(c) Assume `r1` and `r3` to be live-out on the return instruction. Calculate live-ins and live-outs for each node in the control graph. Present your results in a table. (15)

Solution:



node	succ	def	use	out	in	out	in
11				r1 r3	r1 r3	r1 r3	r1 r3
10	11	r3	c	r1 r3	r1 c	r1 r3	r1 c
9	10	r1	d	r1 c	c d	r1 c	c d
8	6, 9		e	c d	c d e	b c d e	b c d e
7	8	e	e	c d e	c d e	b c d e	b c d e
6	7	d	b d	c d e	b c d e	b c d e	b c d e
5	6	e	a	b c d e	a b c d	b c d e	a b c d
4	5	d		a b c d	a b c	a b c d	a b c
3	4	b	r2	a b c	r2 a c	a b c	r2 a c
2	3	a	r1	r2 a c	r1 r2 c	r2 a c	r1 r2 c
1	2	c	r3	r1 r2 c	r1 r2 r3	r1 r2 c	r1 r2 r3

Question 2: Liveness analysis (20 points)

```
l1: if y = 0 goto l2
    q := x / y
    t := q * y
    r := x − t
    x := y
    y := r
    goto l1
l2: return x
```

(a) Construct the control graph for the intermediate code on the left. (2)

(b) Fill in the table below with successor nodes, defined variables, and used variables for each node in the control graph. (3)

(c) Calculate live-ins and live-outs for each node in the control graph in a table on paper. Present your final round of calculation in the table below (■ = live) and name the columns accordingly. (15)

				live-out					live-in				
node	succ	def	use	r	q	t	x	y	r	q	t	x	y
				□	□	□	■	□	□	□	□	□	□
				□	□	□	□	□	□	□	□	□	□
				□	□	□	□	□	□	□	□	□	□
				□	□	□	□	□	□	□	□	□	□
				□	□	□	□	□	□	□	□	□	□
				□	□	□	□	□	□	□	□	□	□
				□	□	□	□	□	□	□	□	□	□
				□	□	□	□	□	□	□	□	□	□