Draw loops from enumerated reaction networks
December 2014

Initializations

```
> restart :
> interface(rtablesize = 400) :
> with(ListTools) :
> with(LinearAlgebra) :
> with(VectorCalculus) :
> with(GraphTheory) :
> with(combinat) :
> with(ArrayTools) :
> with(FileTools) :
> _Envsignum0 := 0 :
>
```

Functions for constructing graph from stoichiometric matrix

```
> findZ := proc(A)
    local Z, n, m, i, j :
      n := Dimension(A)[1] :
      m := Dimension(A)[2] :
      Z := Matrix(n, m) :
   for i from 1 to n by 1 do
     for j from 1 to m by 1 do
         if A[i, j] < 0 then Z[i, j] := z[i, j]; end if;       ### what is the z?
     end do;
  end do:
   return(Z) :
   end proc:
```

Find the DSR graph from labels, A and Z

```
> ##Create signed DSR graph: entries are two matrices and the labels of the nodes
   createDSRgraphsigned := proc(mynodes, A, Z)
     local G, n, m, Adj, varsZ, Zsign, varsA, Asign, X :
     n := Dimension(A)[1] : m := Dimension(A)[2] :
     X := Transpose(Z) :
```

```
    varsZ := indets(X) :
    Zsign := subs(seq(varsZ[i] = 1, i = 1 ..numelems(varsZ)), X) :

   Adj := Matrix(n + m, n + m) :
   Adj[[n + 1 ..n + m], [1 ..n]] := Transpose(map(signum, A)) :
   Adj[[1 ..n], [n + 1 ..n + m]] := Transpose(Zsign) :

   G := GraphTheory[Graph](mynodes, Adj, weighted = true) :
   return(G) :
  end proc:
```

Find the DSR graph from labels and A and return the list of edges:

```
> findedgesDSR := proc(mynodes, A)
    local G, Z :
    Z := findZ(A) :
   G := createDSRgraphsigned(mylabels, A, Z) :
   return(Edges(G, weights)) :
  end proc:
```

```
>
```

Functions for draw loops from graph

Auxiliary procedures

This procedure **c**omputes the polynomial $p_{A, Z}$ in the main text. The input are the matrices A and Z (in the function denoted N and X).

```
> ## compute Mtilde determinant
  computdetS := proc(N, X)
   local M, Mt, F, i, bigdet, n1, s1 :
   n1 := Dimension(N)[1] : s1 := Rank(N) :
   M := N.Transpose(X) :
   Mt := M :
   if s1 < n1 then
     F
       := ReducedRowEchelonForm(Transpose(Matrix([op(NullSpace(Transpose(
     N)))]))) :
    for i from 1 by 1 to Dimension(F)[1] do
       Mt[ArrayTools[SearchArray](F[i])[1]] := F[i] :
    end do:
```

```
    end if:
    bigdet := expand(Determinant(Mt)) :
    return(bigdet) :
  end proc:
```

This function returns the list of monomials that have the wrong sign. The input are the determinant and the wrong sign.

```
> ##Given a determinant and a wrong sign, return the list of wrong monomials
  badterms := proc(deter, mysign)
      local vars, coeflist, monomlist, coeflistsign, wterms, i :
       vars := indets(deter) :
      coeflist := [coeffs(deter, vars, 't')]:
       monomlist := [t]:
      coeflistsign := map(sign, coeflist) :
      wterms := [ ]:
      for i from 1 by 1 to numelems(coeflistsign) do
          if mysign = coeflistsign[i] then wterms := [op(wterms), monomlist[i]] : end if:
      end do:
      return(wterms) :

  end proc:
```

Given a monomial on the entries of a matrix Amatrix, this function finds a matrix from Amatrix such that the variables in the monomial become 1 and the rest are zero.

```
> ##Find submatrix of a matrix corresponding to a monomial
  findmatrix := proc(wmonom, Amatrix)
      local vars, wvarscomp, Anew, i, Anew1 :
      vars := indets(wmonom) :
      wvarscomp := indets(Amatrix) minus vars :
      Anew := subs(seq(wvarscomp[i] = 0, i = 1 ..numelems(wvarscomp)), Amatrix) :
      Anew1 := subs(seq(vars[i] = 1, i = 1 ..numelems(vars)), Anew) :
      return(Anew1) :
  end proc:
```

Find the two submatrices of A and Z corresponding to the monomial, and make A symbolic by introducing a new variable x.

```
> ## Find the two matrices A,Z corresponding to a monomial
  twomatrices := proc(wmonom, A, Z)
      local vars, wvarscomp, Zembed, i, row, col, Aembed, Aembedx, nZ, X :
      X := Transpose(Z) :
      vars := indets(wmonom) :
      wvarscomp := indets(X) minus vars :
      Zembed := subs(seq(wvarscomp[i] = 0, i = 1 ..numelems(wvarscomp)), X) :
      row, col := ArrayTools[SearchArray](Zembed) :
```

```
    Zembed := Zembed[convert(row, list), convert(col, list)] :
    nZ := numelems(vars) :
    Aembed := A[convert(col, list), convert(row, list)] :
   Aembed := map(signum, Aembed) :
   row, col := ArrayTools[SearchArray](Aembed) :
   Aembedx := Matrix(nZ, nZ) :
   for i from 1 by 1 to numelems(col) do
    Aembedx[row[i], col[i]] := Aembed[row[i], col[i]]·x_i :
   end do:
   return(Aembedx, Zembed) :
end proc:
```

Extract the indices of the species and the reaction in the given monomial in the variables of Z

```
> ## Extract indices of species and reaction in the monomial from Z
extractsr :=proc(wmonom, Z)
    local vars, wvarscomp, Zembed, i, row, col, X :
    X := Transpose(Z) :
    vars := indets(wmonom) :
    wvarscomp := indets(X) minus vars :          ## indeterminates not in the monomial
    Zembed := subs(seq(wvarscomp[i] = 0, i = 1 ..numelems(wvarscomp)), X) :
     ##set the entries of the indeterminates not in the monomial to zero
    row, col := ArrayTools[SearchArray](Zembed) :
     ##find the nonzero entries of the resulting matrix.
    return(row, col) :  ##return the species and reaction indices
 end proc:
```

```
> ##Create DSR graph: entries are two matrices and the labels of the nodes
createDSRgraph :=proc(mynodes, A, Z)
   local G, n, m, Adj, varsZ, Zsign, varsA, Asign, X :
   n := Dimension(A)[1] : m := Dimension(A)[2] :
   X := Transpose(Z) :
   varsZ := indets(X) :
   Zsign := subs(seq(varsZ[i] = 1, i = 1 ..numelems(varsZ)), X) :
   varsA := indets(A) :
   Asign := subs(seq(varsA[i] = 1, i = 1 ..numelems(varsA)), A) :

  Adj := Matrix(n + m, n + m) :
  Adj[[n + 1 ..n + m], [1 ..n]] := Transpose(map(signum, Asign)) :
  Adj[[1 ..n], [n + 1 ..n + m]] := Transpose(Zsign) :

   G := GraphTheory[Graph](mynodes, Adj, weighted = true) :
   return(G) :
 end proc:
>
```

This function selects the subgraphs that give rise to the monomials with the wrong sign.

```
> ## Select the subgraphs that correspond to the wrong terms of A and Z
graphlist := proc(mydet, A, Z)
 local srlist, row, col, Gsub, s, wsign, wrongterms, k, wcurrent, Aembedx, Zembed, detZ,
     detAx, wsignA, wrongtermsA, wcurrentA, j, Aembedx1, mynodes :
Gsub := [ ] :
 srlist := [ ] :
 s := Rank(A) :
wsign := (-1)^(s + 1) :                        ## find wrong sign
wrongterms := badterms(mydet, wsign) :   ## select the monomials with the wrong sign
 for k from 1 by 1 to numelems(wrongterms) do
     ## for each such monomial, find the associated subgraph
     wcurrent := wrongterms[k] :
     row, col := extractsr(wcurrent, Z) :
     ## find the indices of the species and the reactions in the monomial
    mynodes := [seq(S_col[i], i = 1 ..numelems(col)), seq(R_row[i], i = 1
      ..numelems(row))] :
     Aembedx, Zembed := twomatrices(wcurrent, A, Z) :
     ## the returned Zembed is giving half of the edges of the subgraphs
     detZ := subs(seq(indets(Zembed)[i] = 1, i = 1 ..numelems(indets(Zembed))),
      Determinant(Zembed)) :
    detAx := expand(Determinant(Aembedx)) :
     wsignA := wsign·detZ :
    wrongtermsA := badterms(detAx, wsignA) :
     ## select the monomials with the wrong sign of the subsystem
     for j from 1 by 1 to numelems(wrongtermsA) do
         wcurrentA := wrongtermsA[j] :
         Aembedx1 := findmatrix(wcurrentA, Aembedx) :
     ## find the other half of the edges of the subgraphs
         Gsub := [op(Gsub), createDSRgraph(mynodes, Aembedx1, Zembed)] :
    end do:
  end do:
  return(Gsub) :  ##return the list of graphs
 end proc:
```

Given a list of edges that form a loop, the function returns the edges ordered such that connected they form the loop.

```
> ## Order the edges to have a loop
orderedge := proc(myedges)
   local orderededges, endpoint, total, control, k :
  orderededges := [myedges[1]] :
  endpoint := myedges[1][1][2] :
  total := numelems(myedges) :
 while numelems(orderededges) < total do
    control := 0 : k := 2 :
    while control = 0 do
       if endpoint = myedges[k][1][1] then
```

```
        orderededges := [op(orderededges), myedges[k]] :
        control := 1 :
        endpoint := myedges[k][1][2] :

      end if:
      k := k + 1 :
    end do:
  end do:
  return(orderededges) :
end proc:
```

Find the sequence of signs of the loop

```
> ##Extract the  sequence  of signs of a loop
extractsign := proc(orderededges)
    local graphsign, i :
    graphsign := [ ] :
   for i from 1 by 1 to numelems(orderededges) do
    graphsign := [op(graphsign), orderededges[i][2]] :
   end do:
  return(graphsign) :
 end proc:
```

Given a list of graphs, we find the positive feedback loops that they contain and return the sign pattern of each positive feedback loop as well (as those given in Table 1 in the main text).

```
> ##Find the positive feedback loops in the list of graphs
positivefeed := proc(Gsub)
     local selected, j, mygraph, Gsubcomp, k, mycomp, newgraph, wedges, myprod, i,
      signcycle :
     selected := [ ] :
    signcycle := [ ] :
    Gsubcomp := [ ] :
    for j from 1 by 1 to numelems(Gsub) do
      mygraph := Gsub[j] :
     Gsubcomp := ConnectedComponents(mygraph) :
     for k from 1 by 1 to numelems(Gsubcomp) do
       mycomp := Gsubcomp[k] :
       newgraph := InducedSubgraph(mygraph, mycomp) :
       wedges := Edges(newgraph, weights) :
       myprod := mul(wedges[i][2], i = 1 ..numelems(wedges)) :
       if myprod = 1 then                ##if the loop is positive, select it
           selected := [op(selected), [op(wedges)]] :
      end if:
     end do:
   end do:
```

```
    selected := ListTools[MakeUnique](selected) :
    for k from 1 by 1 to numelems(selected) do
      selected[k] := orderedge(selected[k]) :
      signcycle := [op(signcycle), extractsign(selected[k])] :
    end do:
    return(selected, signcycle) :
  end proc:
```

The main procedure to find the positive loop is the following:

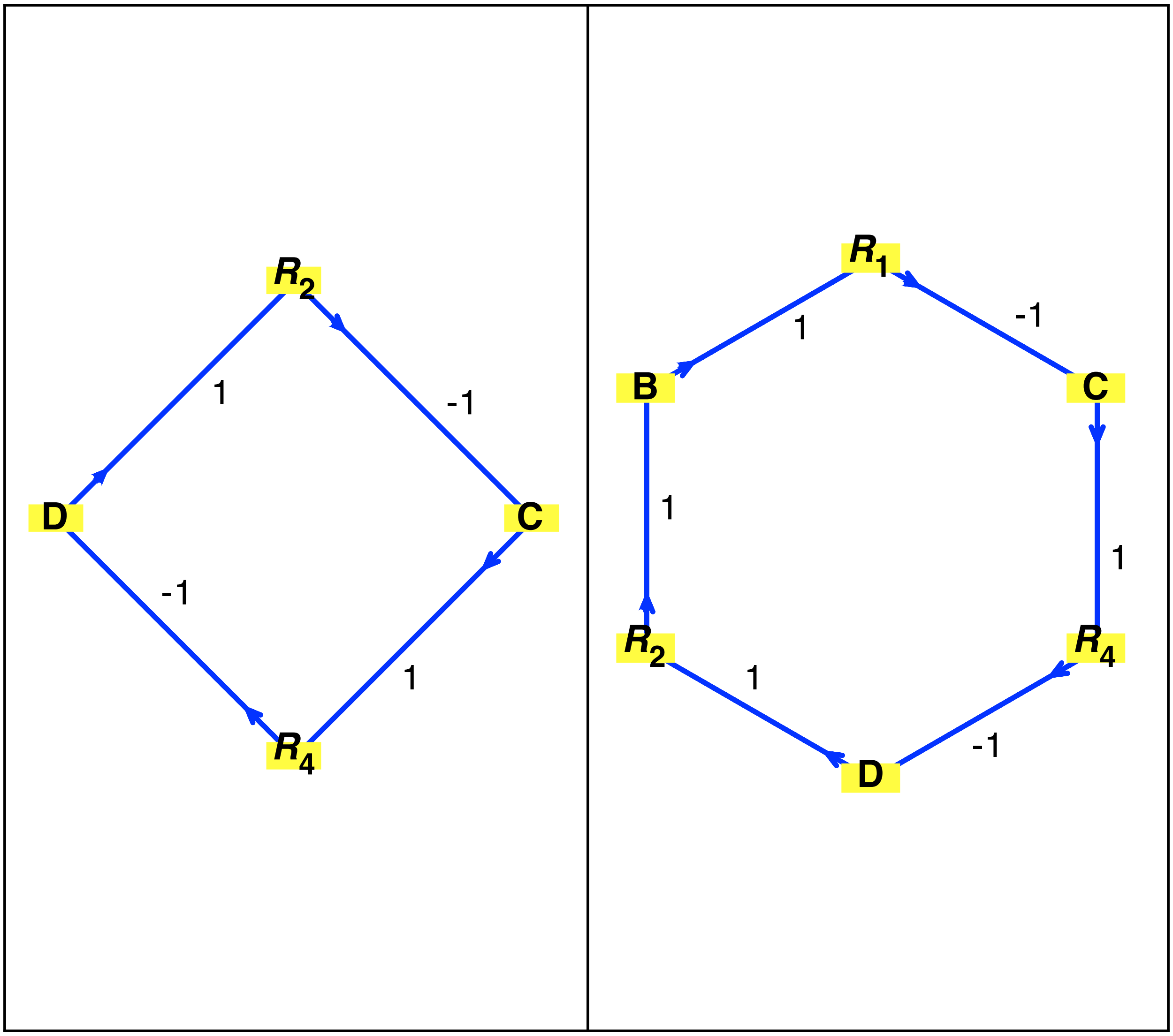
```
> ##main program: find the positive loops
findloops :=proc(A, Z)
  local Gsub, selected, signcycle, mydet :
  mydet := computdetS(A, Z) :  ##find the polynomial p_{A, Z}
  Gsub := graphlist(mydet, A, Z) :
    ##find the list of subgraphs corresponding to the wrong signs
  selected, signcycle := positivefeed(Gsub) :
    ##find the positive feedback loops and their sign pattern
  return(selected) :
end proc:
```

The second main procedure of the method is the function that draws the selected positive feedback loops. It requires a list with the names of the nodes (see the examples below)

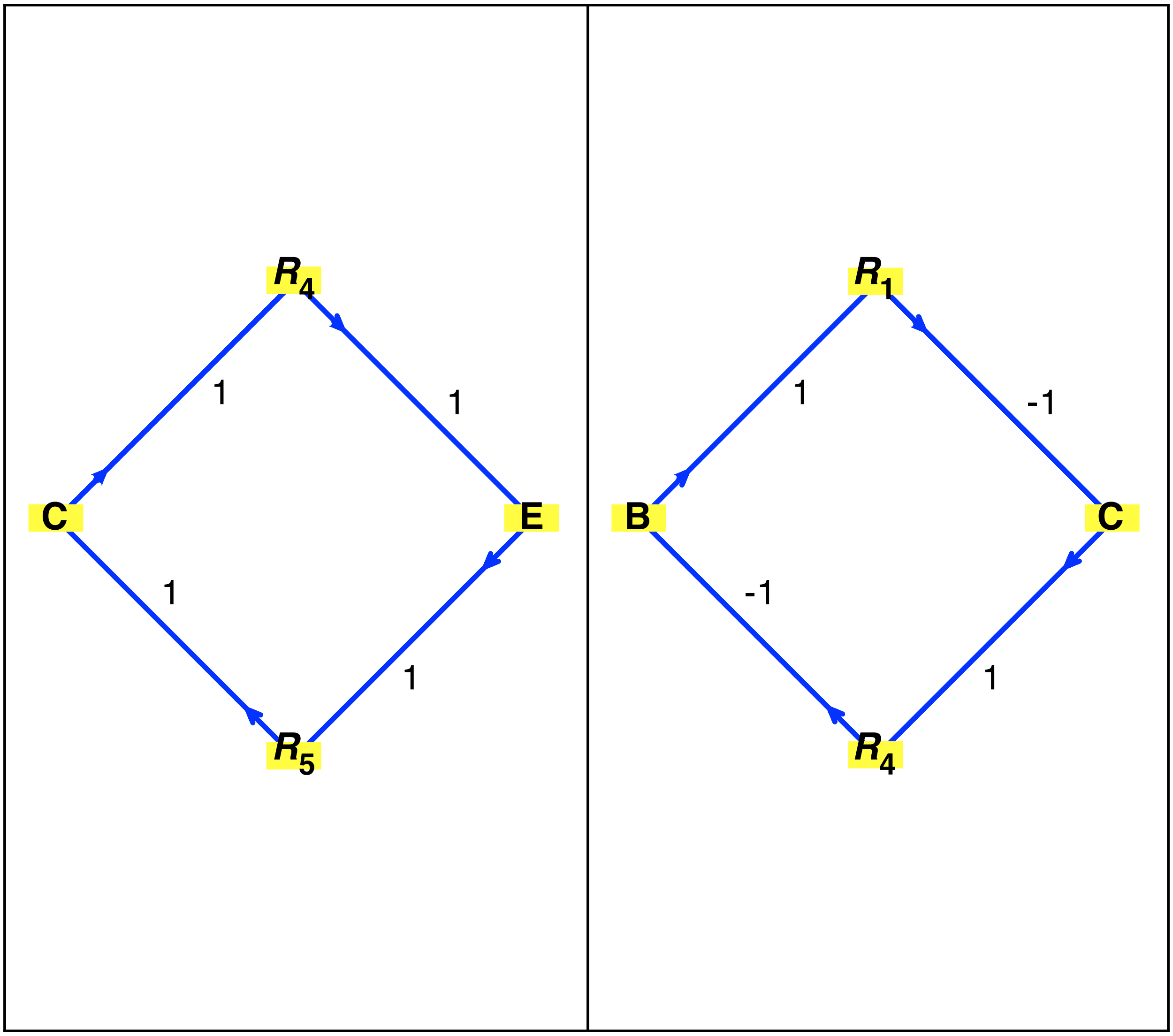
```
> ## draw the positive feedback loops
drawloops :=proc(selected, speciesord)
  local loops, i, vertices, speciesdic, selected2 :
  loops := [ ] :
  speciesdic := {seq(S_i = speciesord[i], i = 1 ..numelems(speciesord))} :
  selected2 := subs(speciesdic, selected) :
for i from 1 by 1 to numelems(selected2) do
      vertices := ListTools[MakeUnique]([seq(op(selected2[i][j][1]), j = 1
      ..numelems(selected2[i]))]) :
      loops := [op(loops), Digraph(vertices, {op(selected2[i])})] :
  end do:
DrawGraph(loops, style = circle);

end proc:
>
```

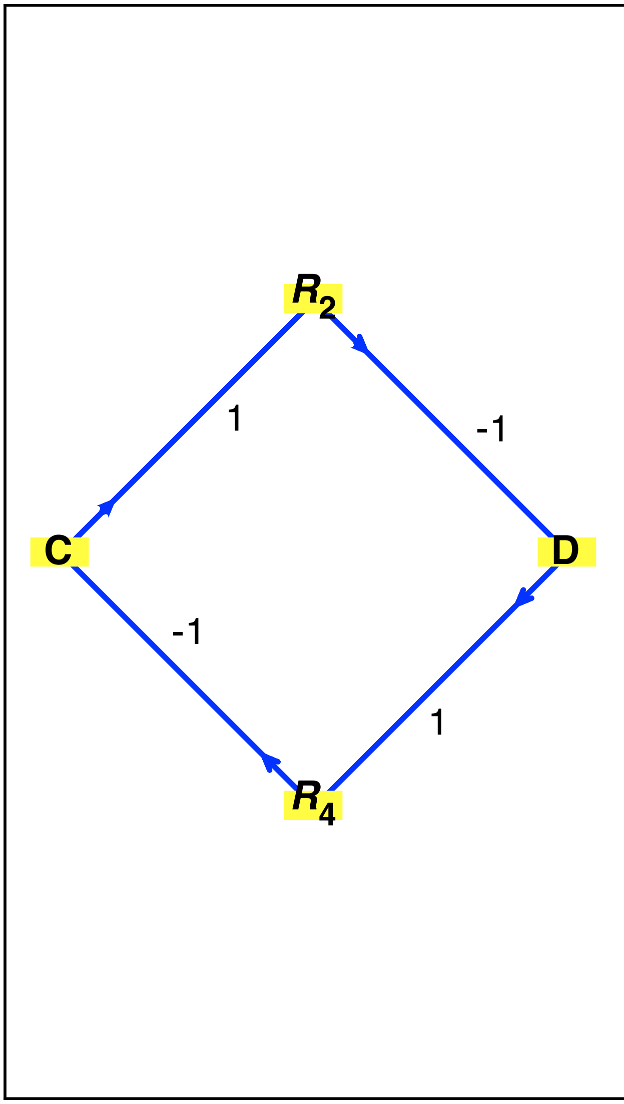
```
> uniquefolder := "5species/nonmultistationary/unique_competitionloop_intersectingloops" :
> speciesord := ["A", "B", "C", "D", "E"] :
> uniquefiles := ListDirectory(uniquefolder) :
> m := nops(uniquefiles) :
> for i from 1 to m by 1 do uni := op(i, uniquefiles) : A := ImportMatrix(cat(uniquefolder, "/",
      uni)) : Z := findZ(A) : selected := findloops(A, Z) : printf("No. %d: %s \n", i, uni);
      print(drawloops(selected, speciesord)); end do:
No. 1: injective1_2962.csv
```

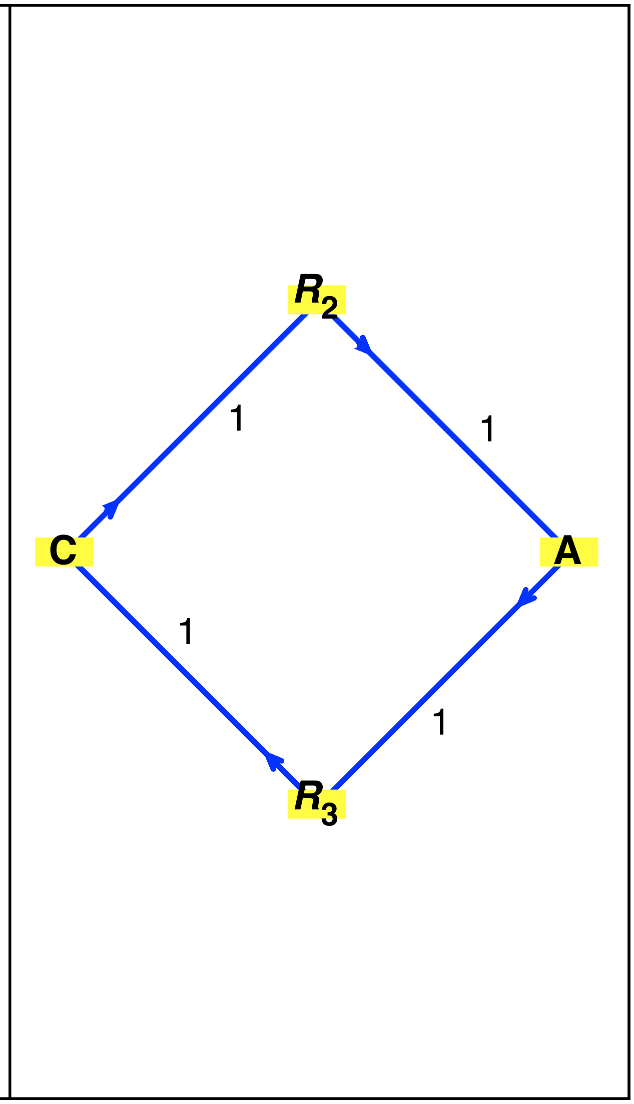



```
No. 2: injective1_3111.csv
```

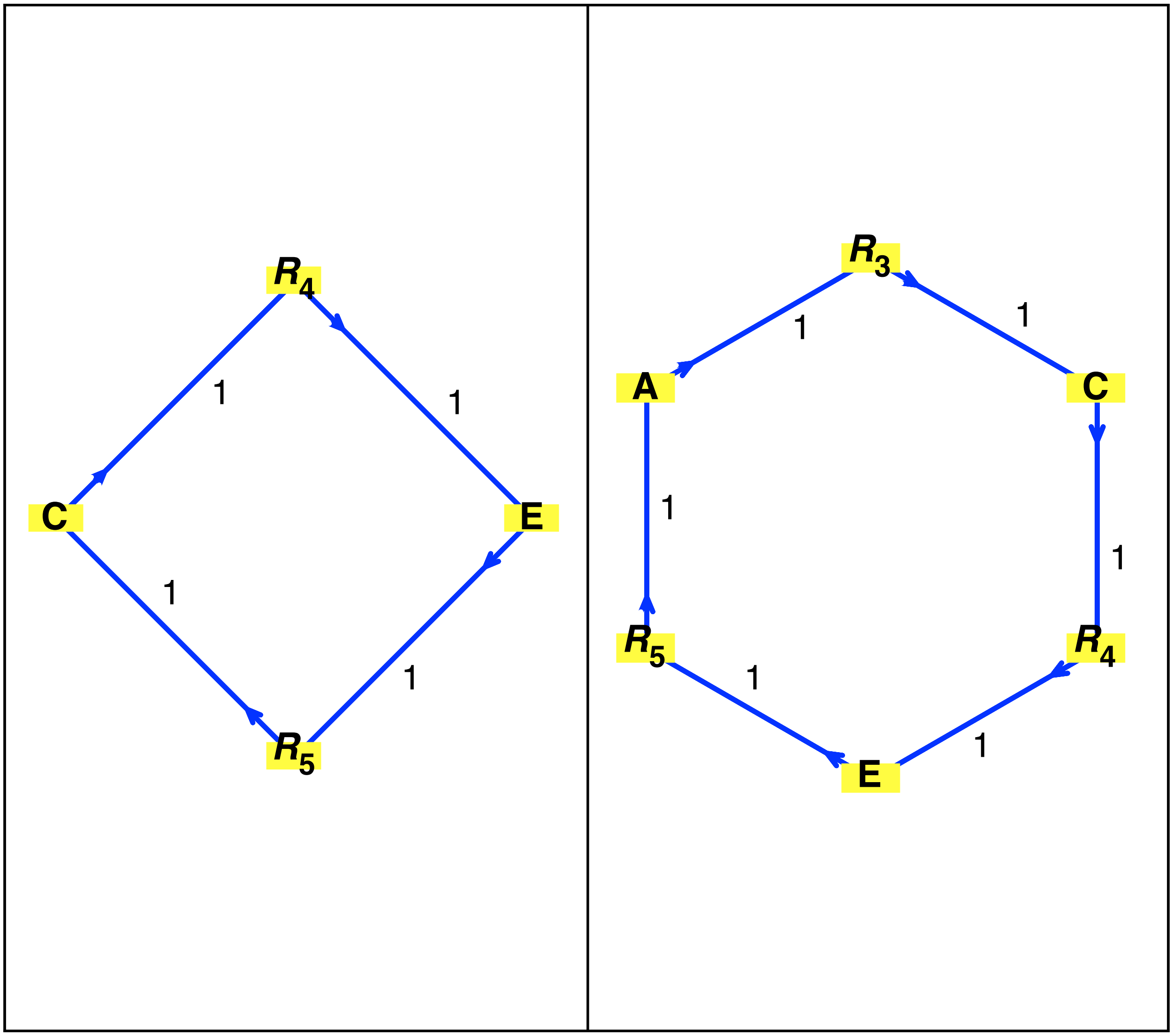


No. 3: injective1_3119.csv

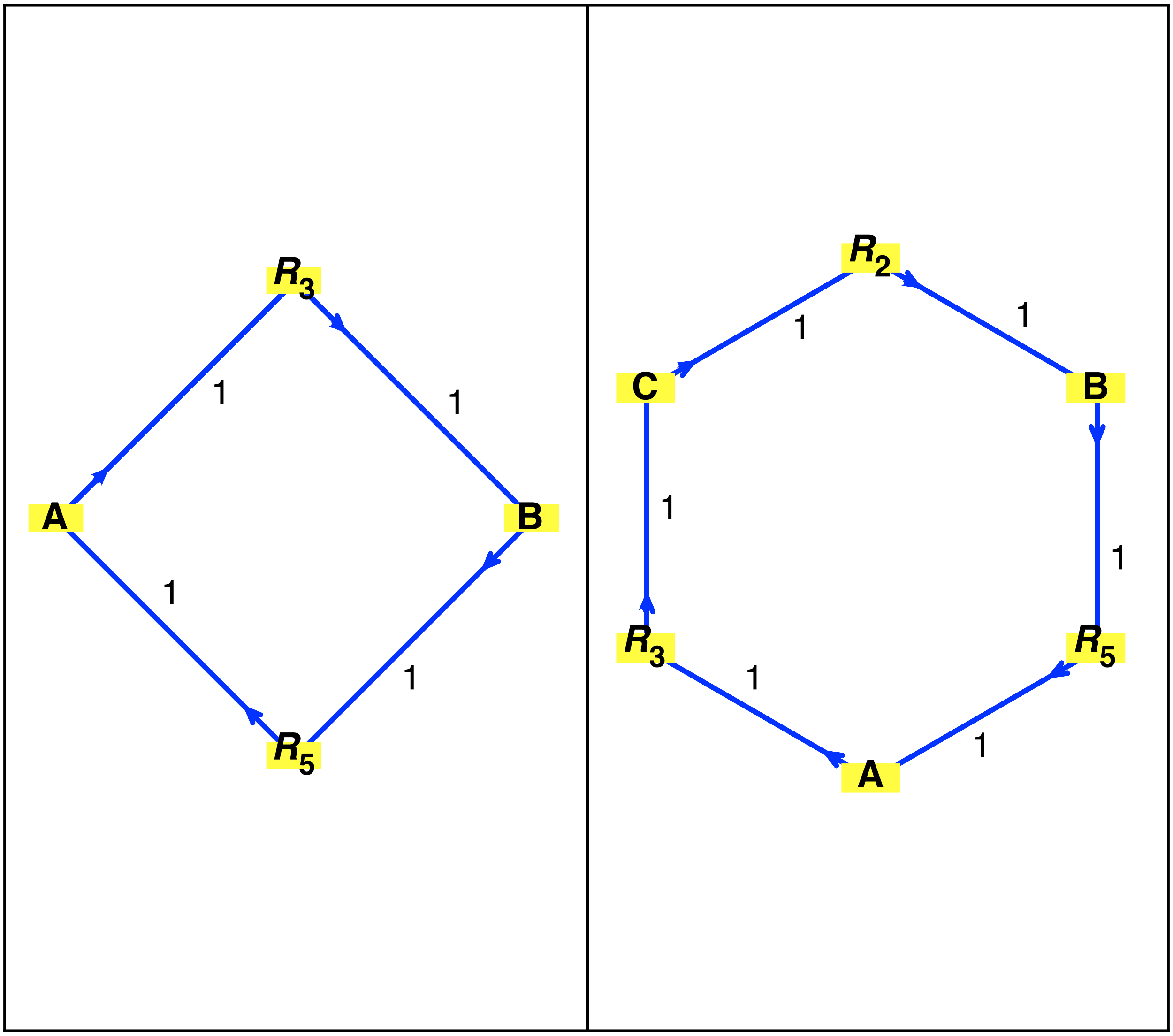


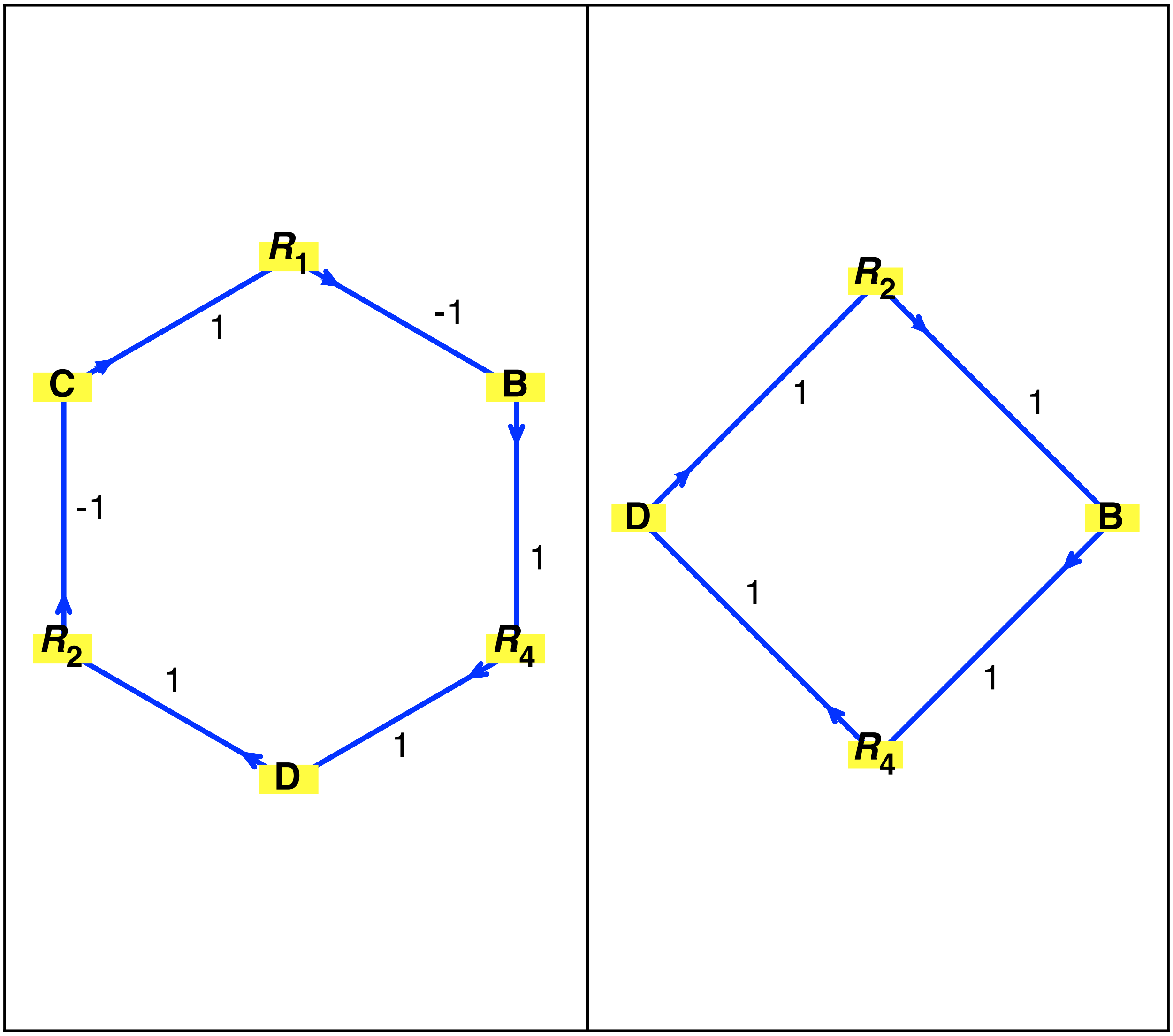


No. 4: injectiveEx1_1267.csv

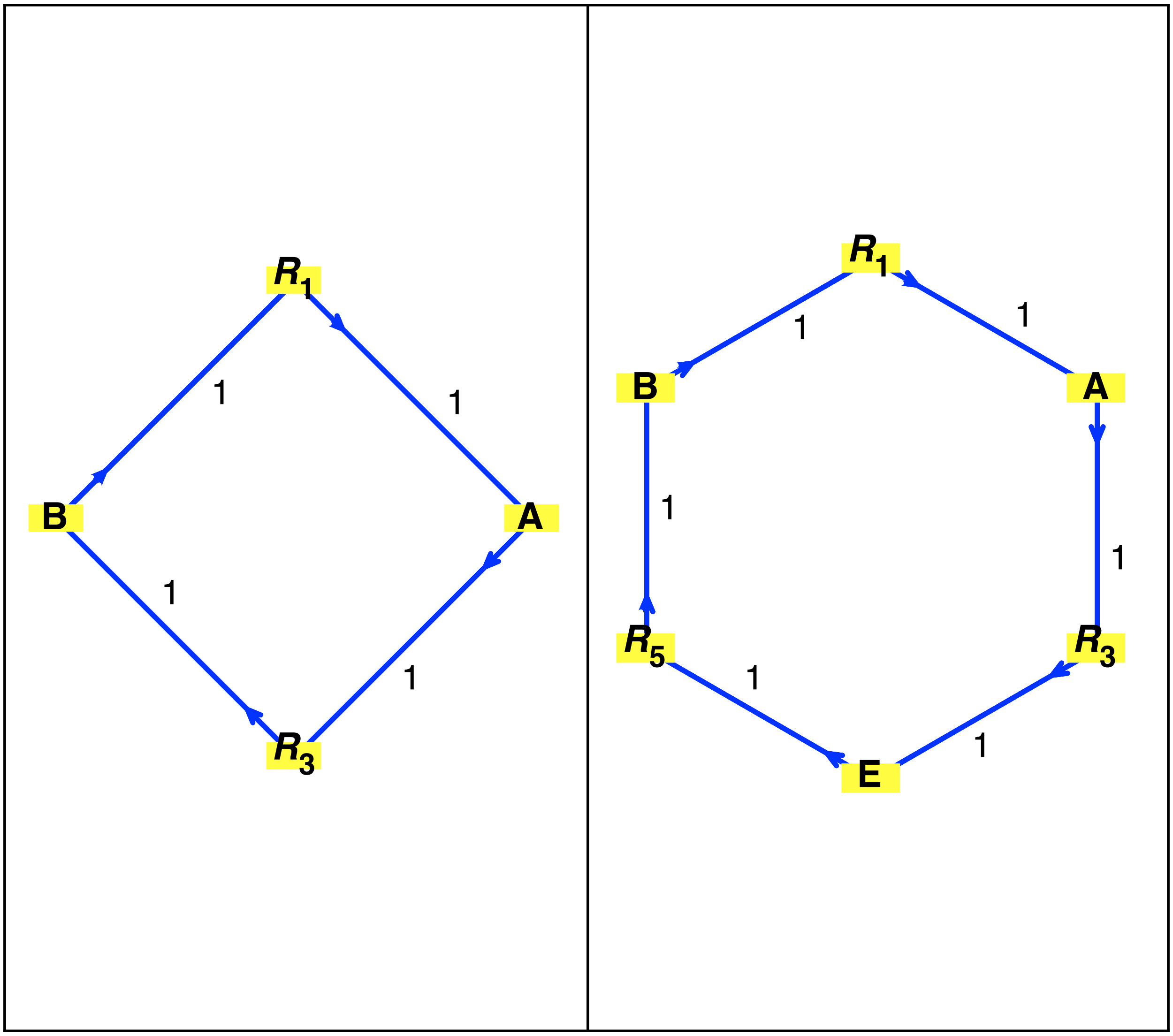


No. 5: injectiveEx1_2956.csv

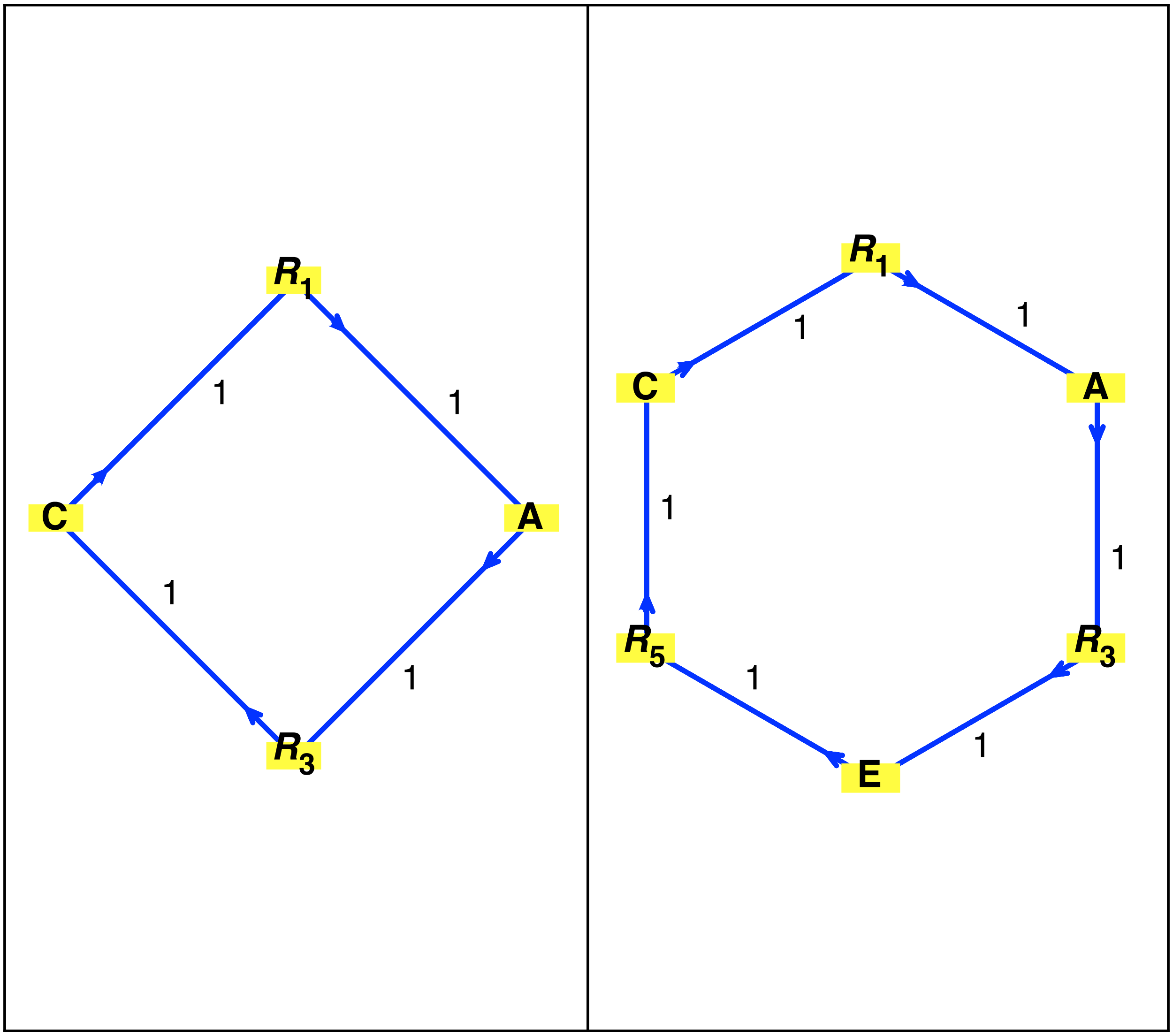

R_3
1
1
A
B
1
1
R_5
R_2
1
1
C
B
1
1
R_3
R_5
1
1
A



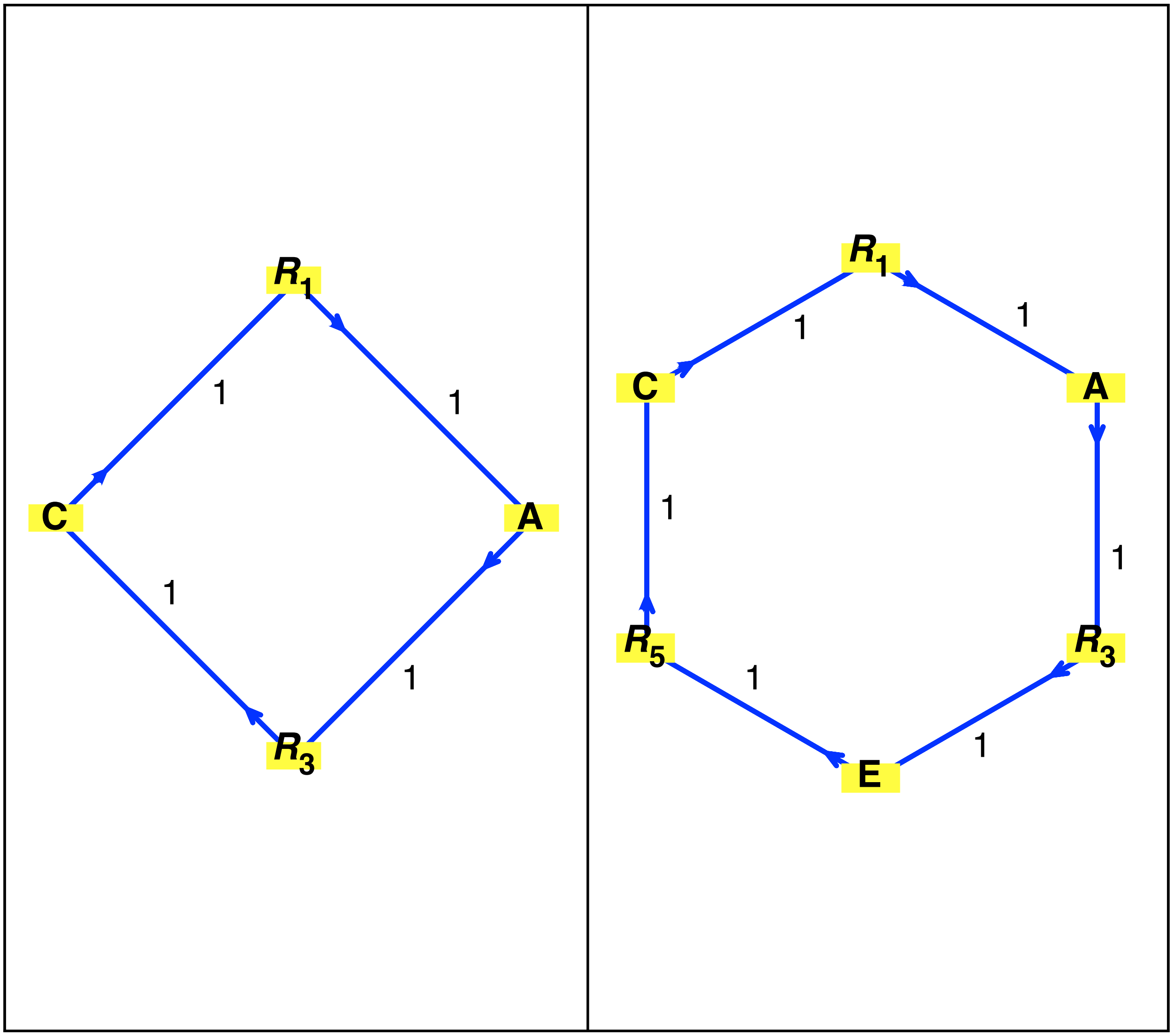
No. 6: injectiveEx1_2979.csv

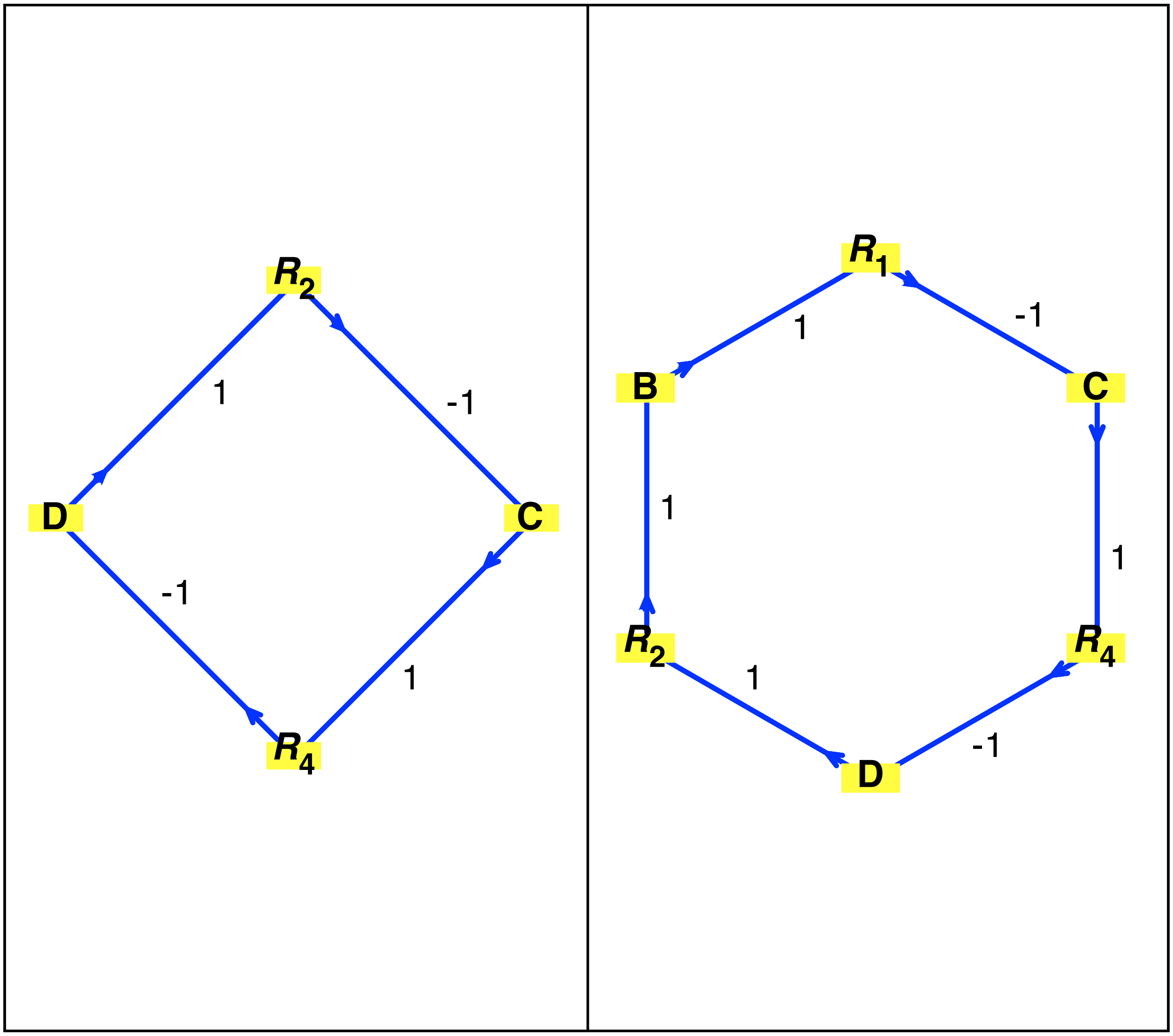


No. 7: injectiveEx1_2987.csv

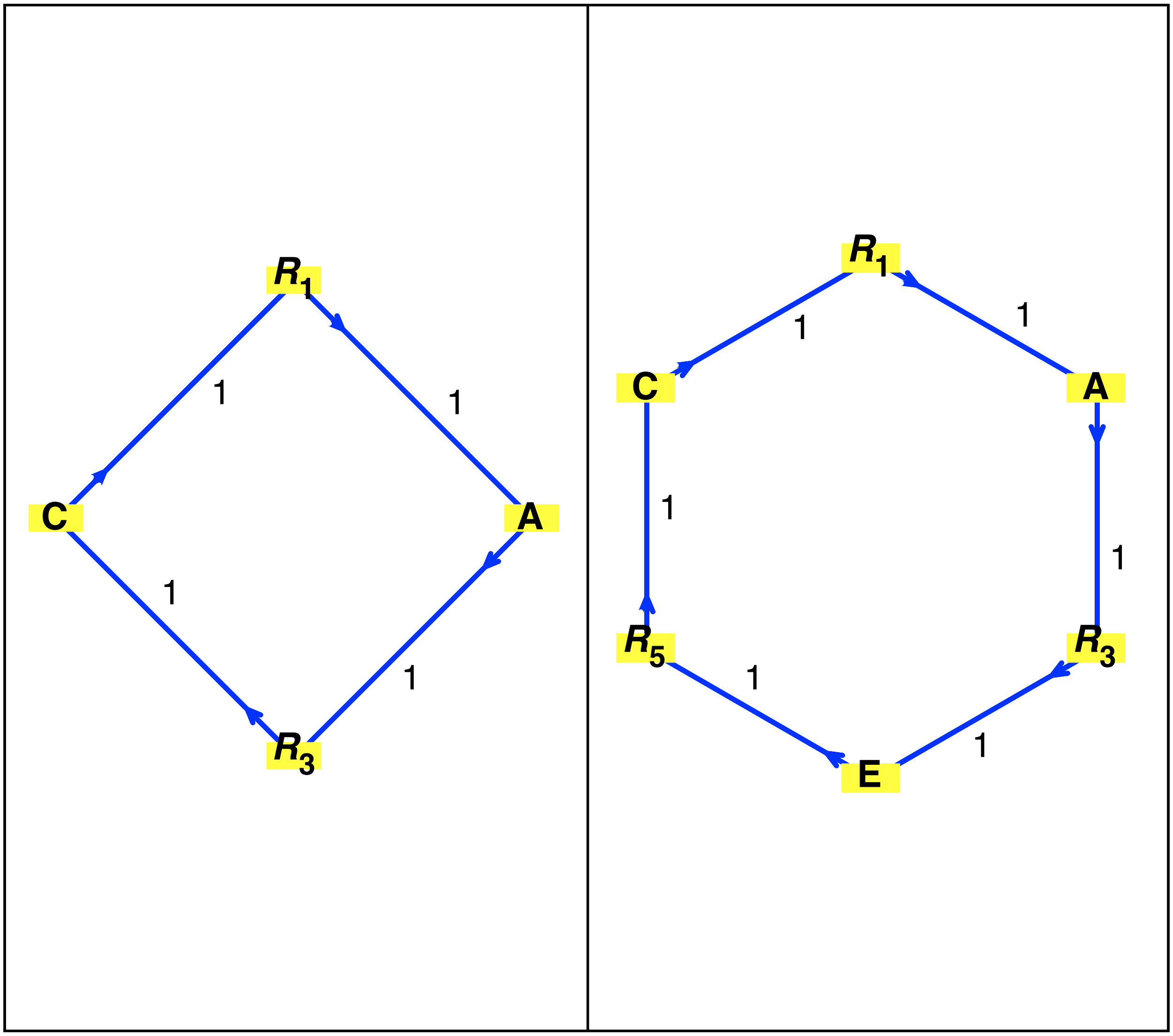


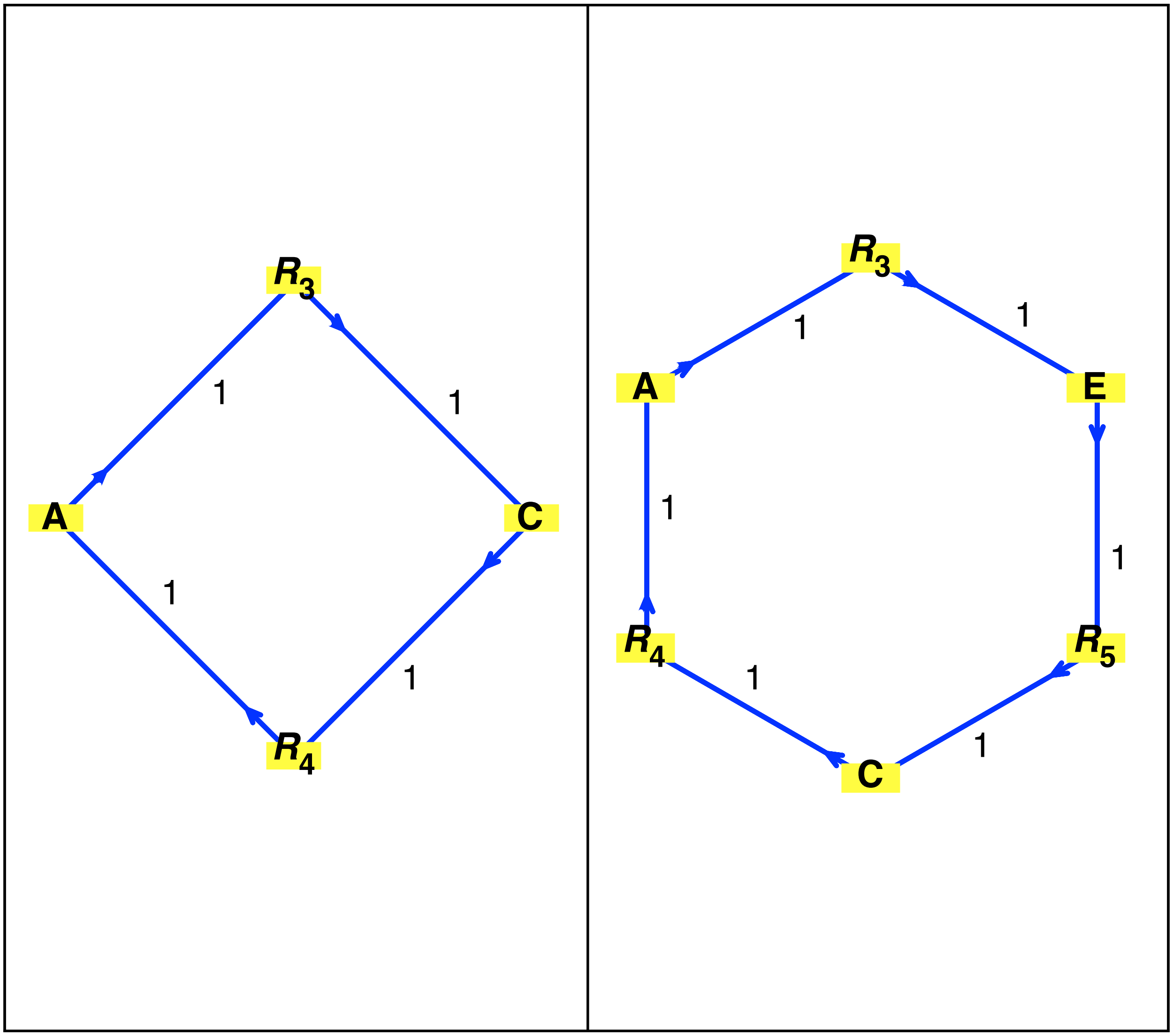
No. 8: injectiveEx1_2988.csv


R_1
1
1
C
A
1
1
R_3
R_1
1
1
C
A
1
1
R_5
R_3
1
1
E

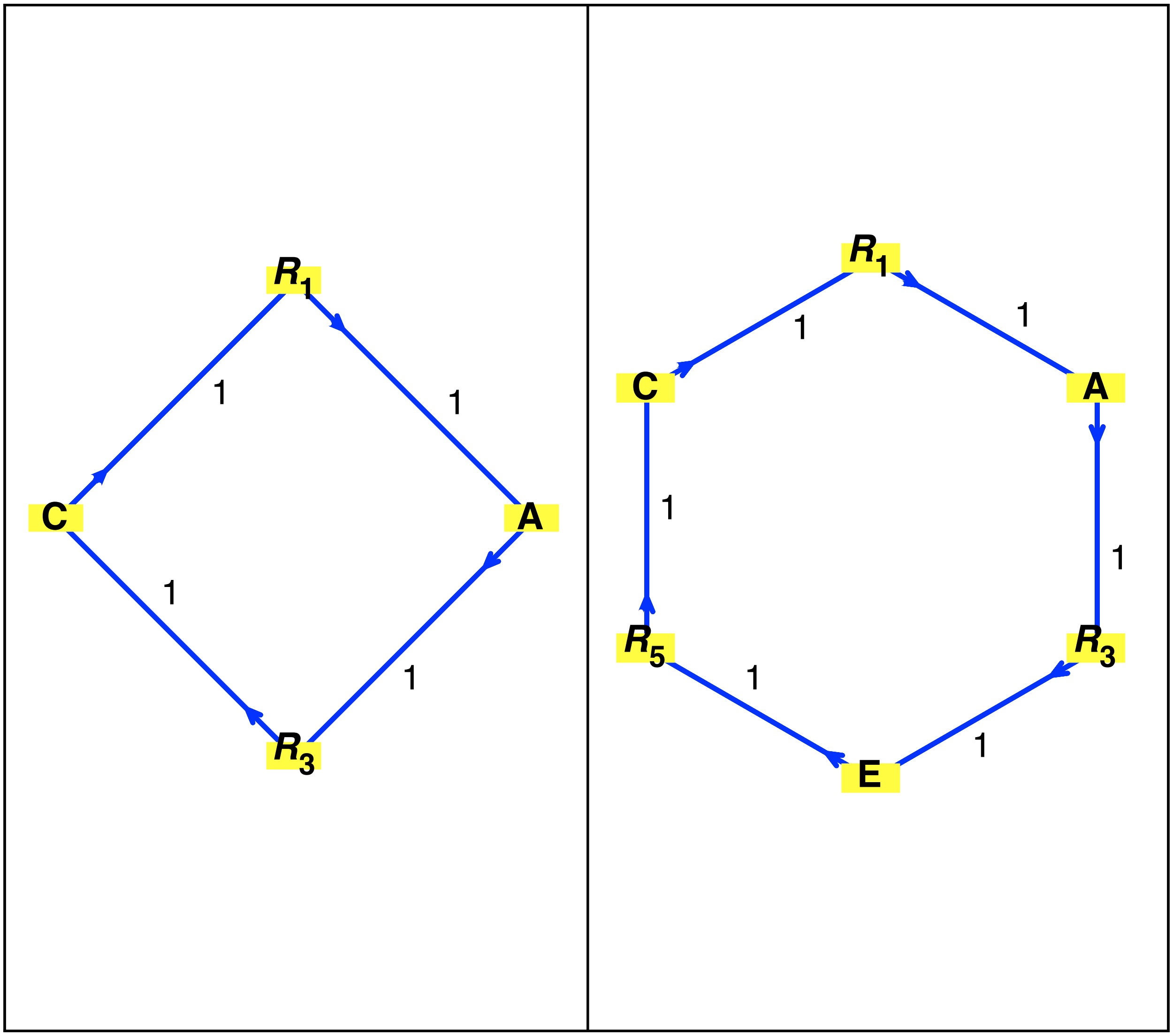


No. 9: injectiveEx1_2989.csv

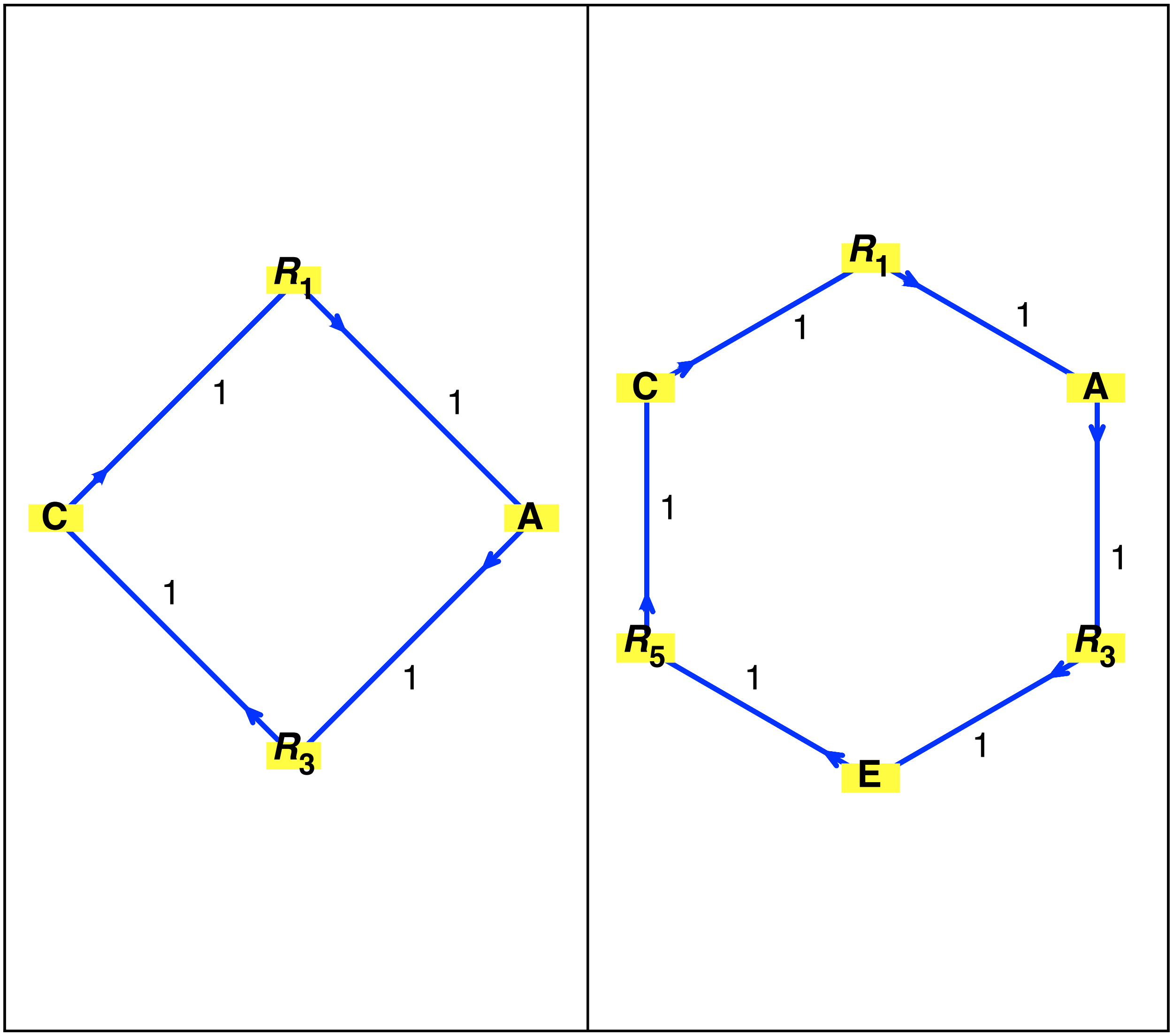

R_1
C
A
R_3
1
1
1
1
R_1
C
A
R_5
R_3
E
1
1
1
1
1
1



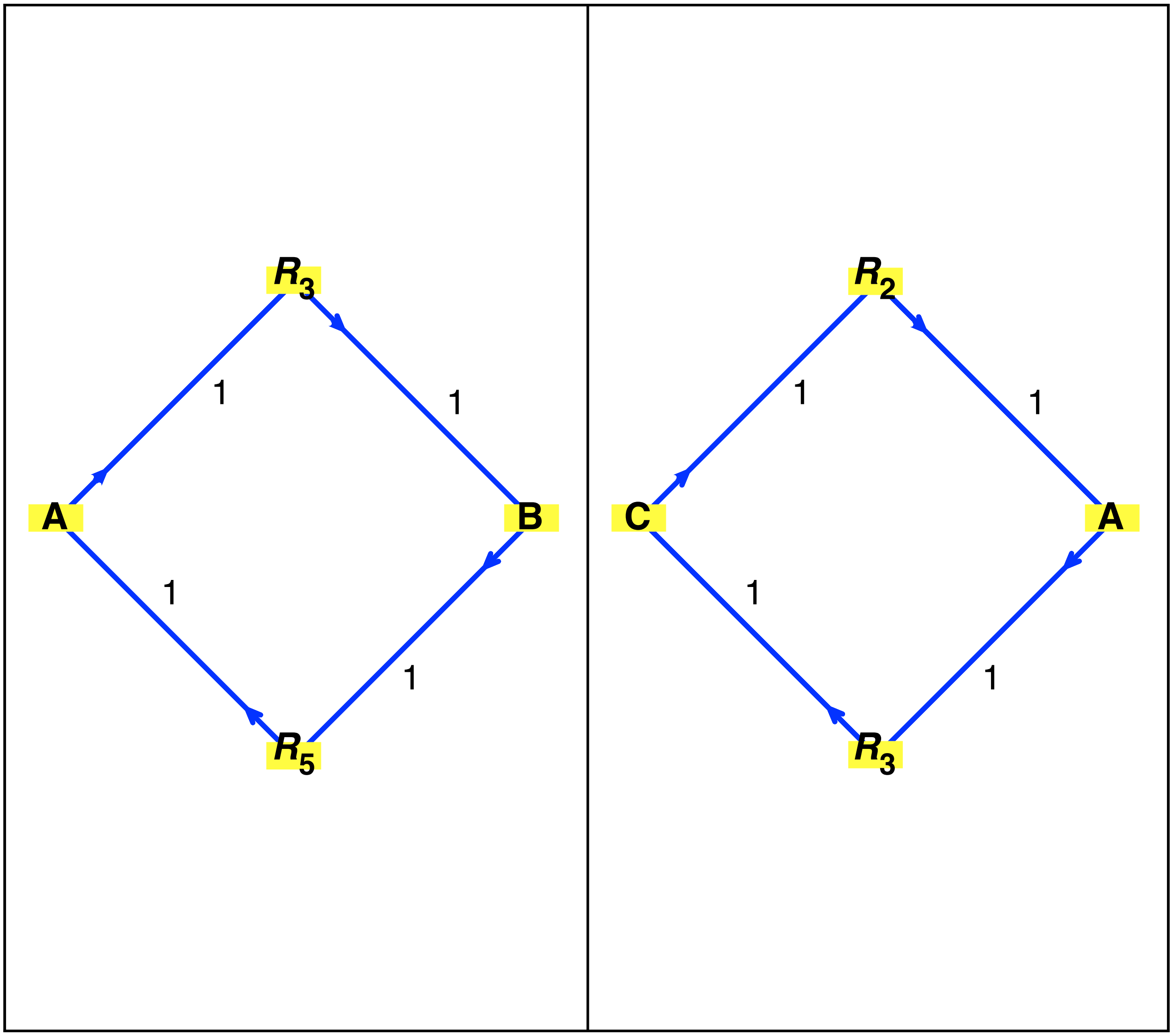
No. 10: injectiveEx1_2991.csv



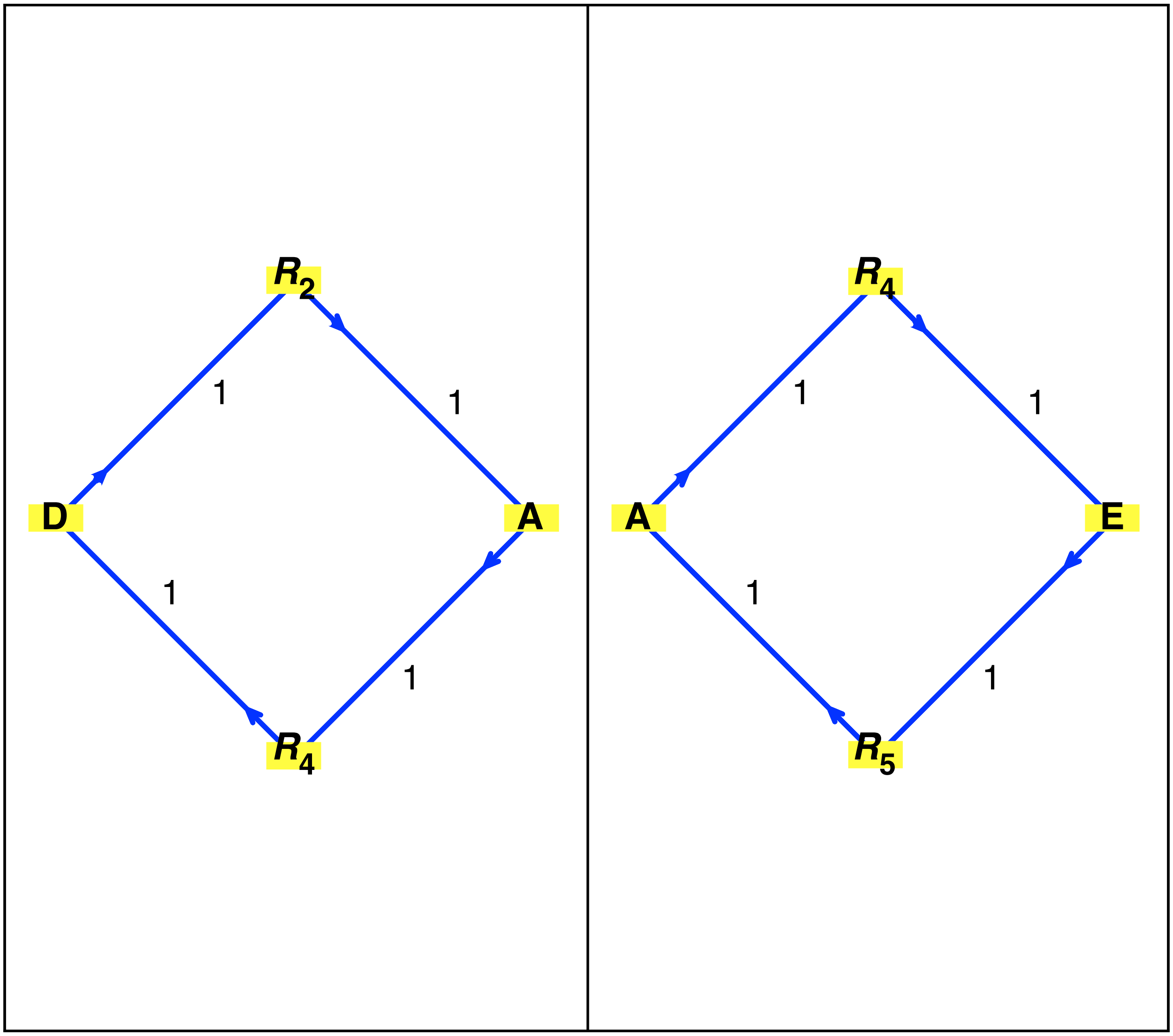
No. 11: injectiveEx1_2993.csv



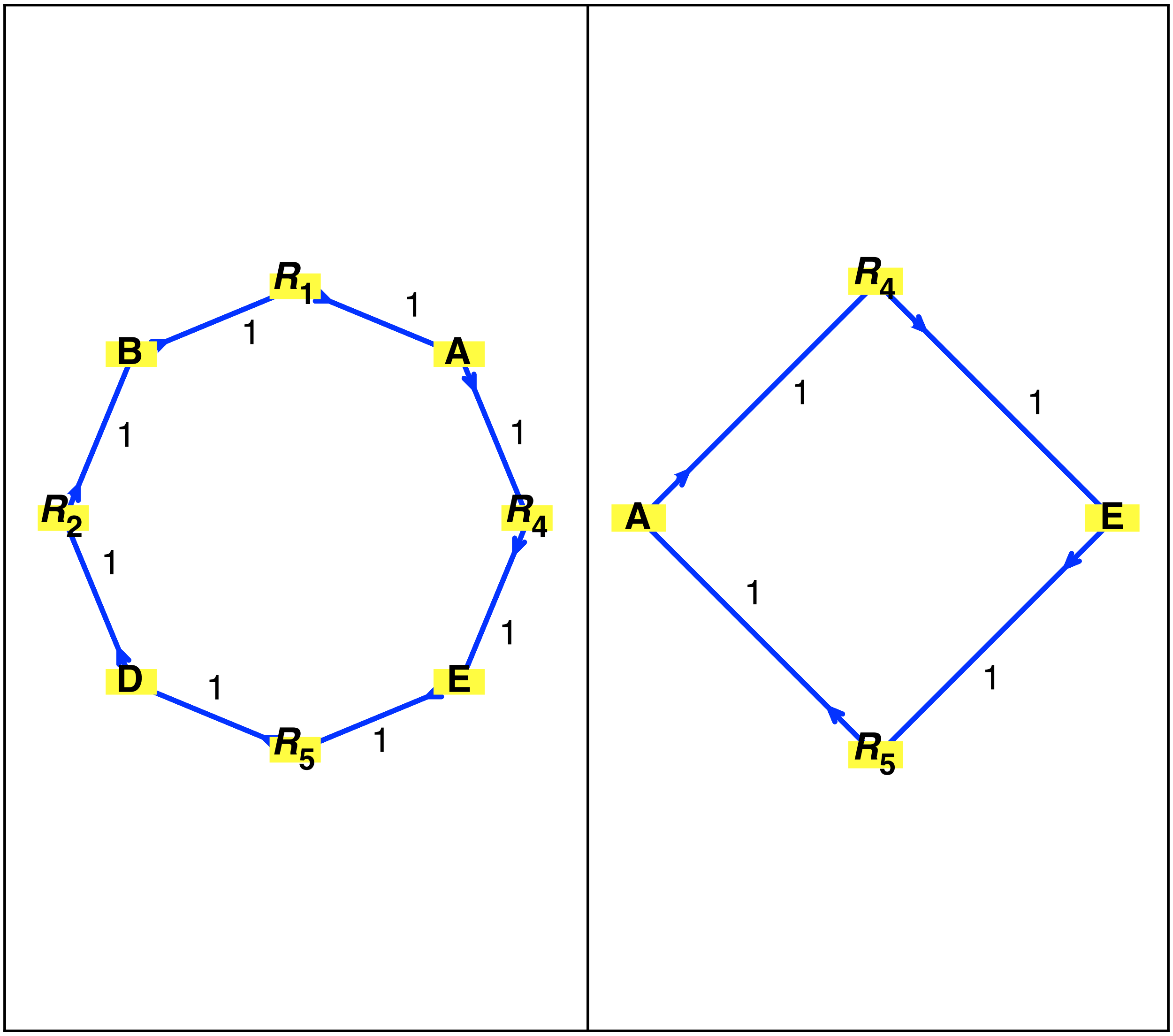
No. 12: injectiveEx1_3103.csv



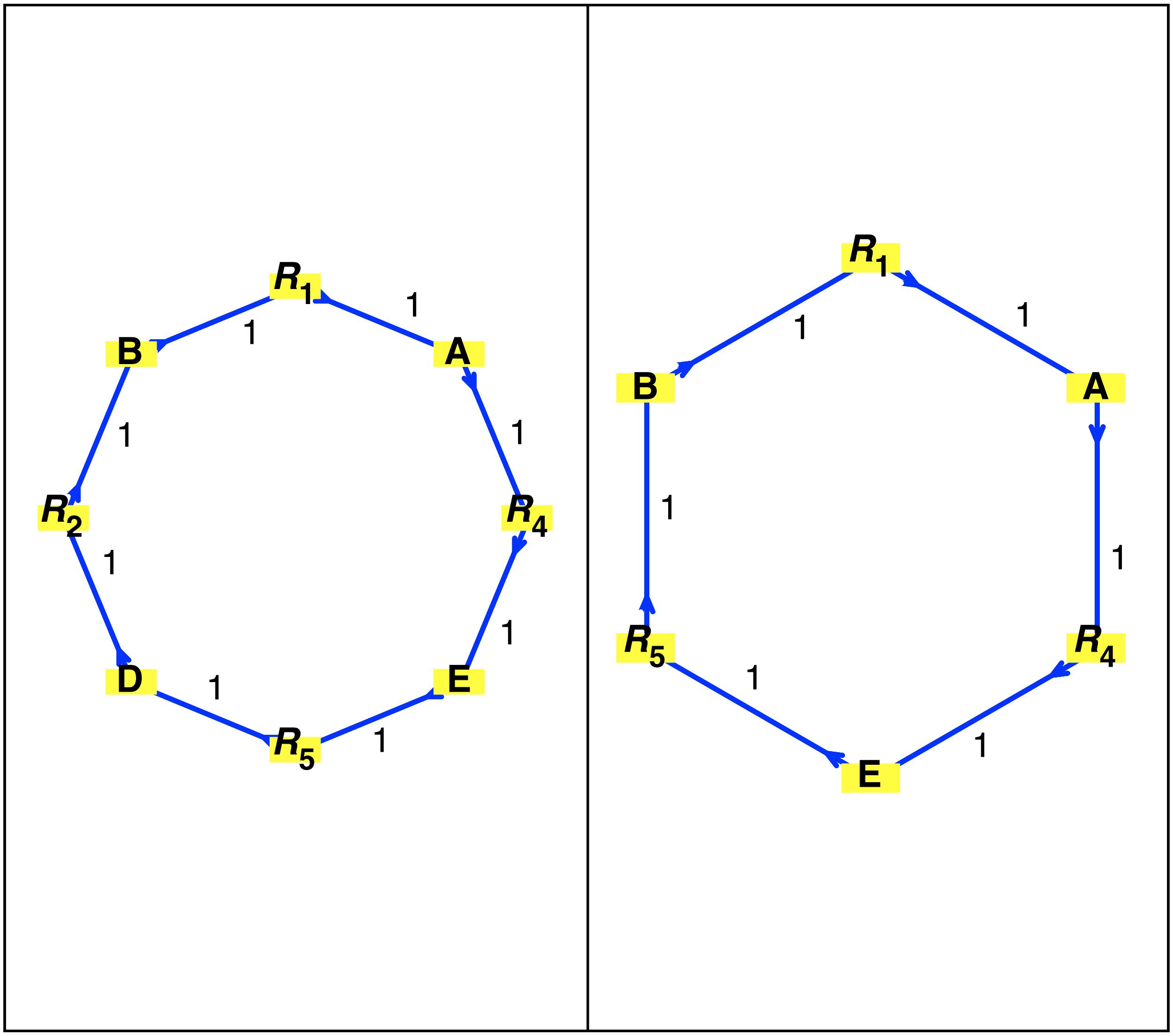
R_3
1
1
A
B
1
1
R_5
R_2
1
1
C
A
1
1
R_3



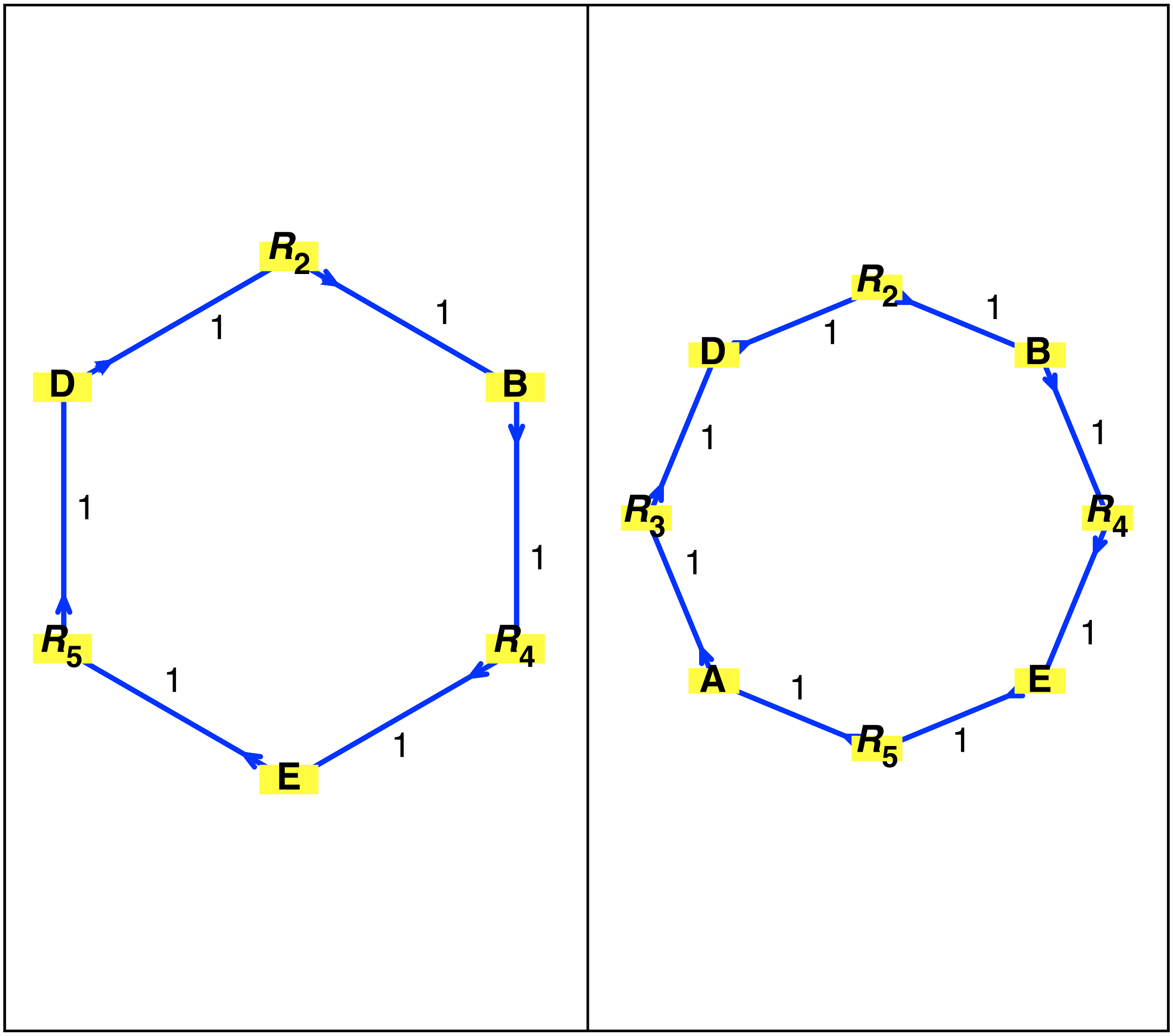
No. 13: injectiveEx3_1250.csv



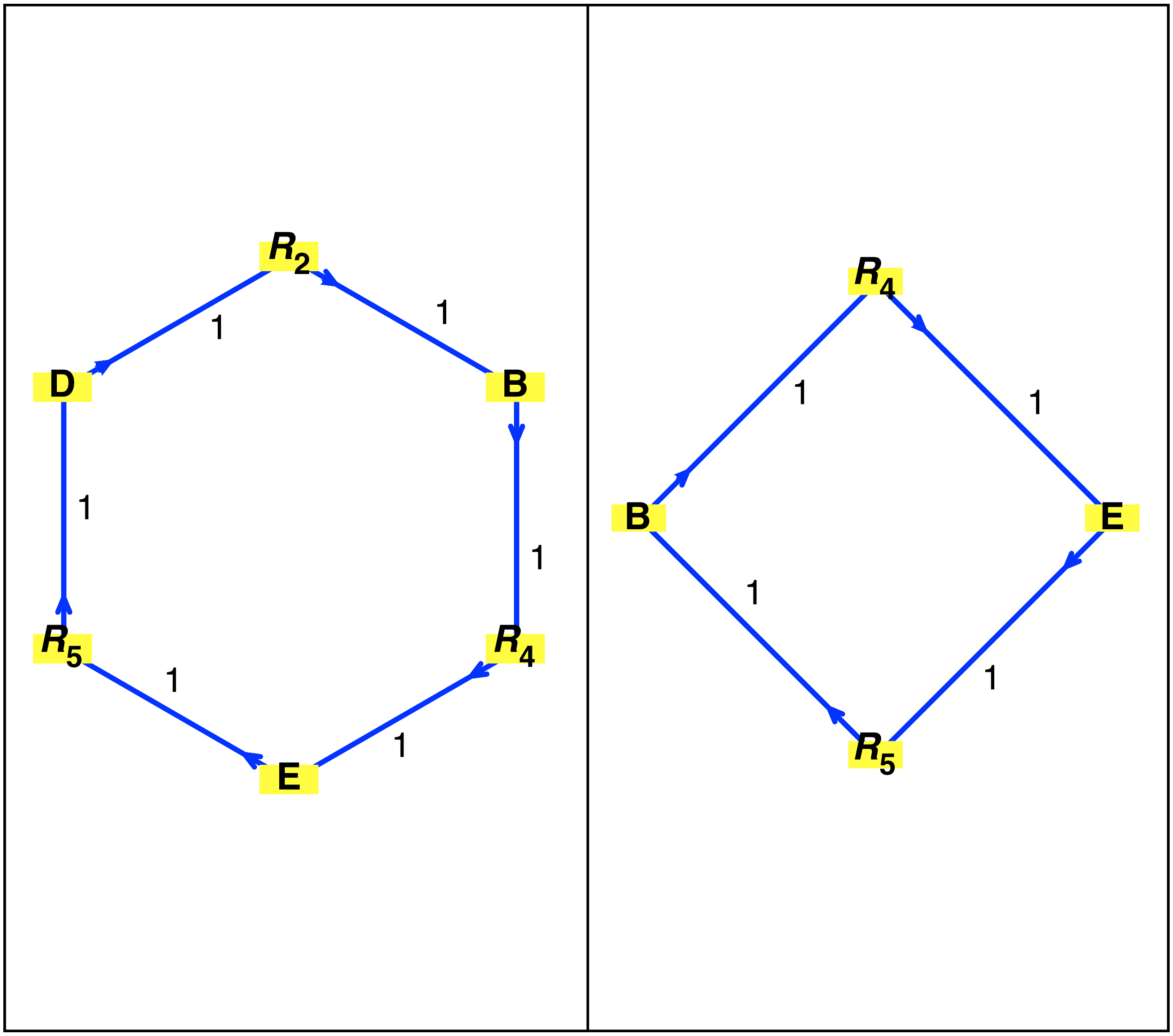
No. 14: injectiveEx3_1252.csv



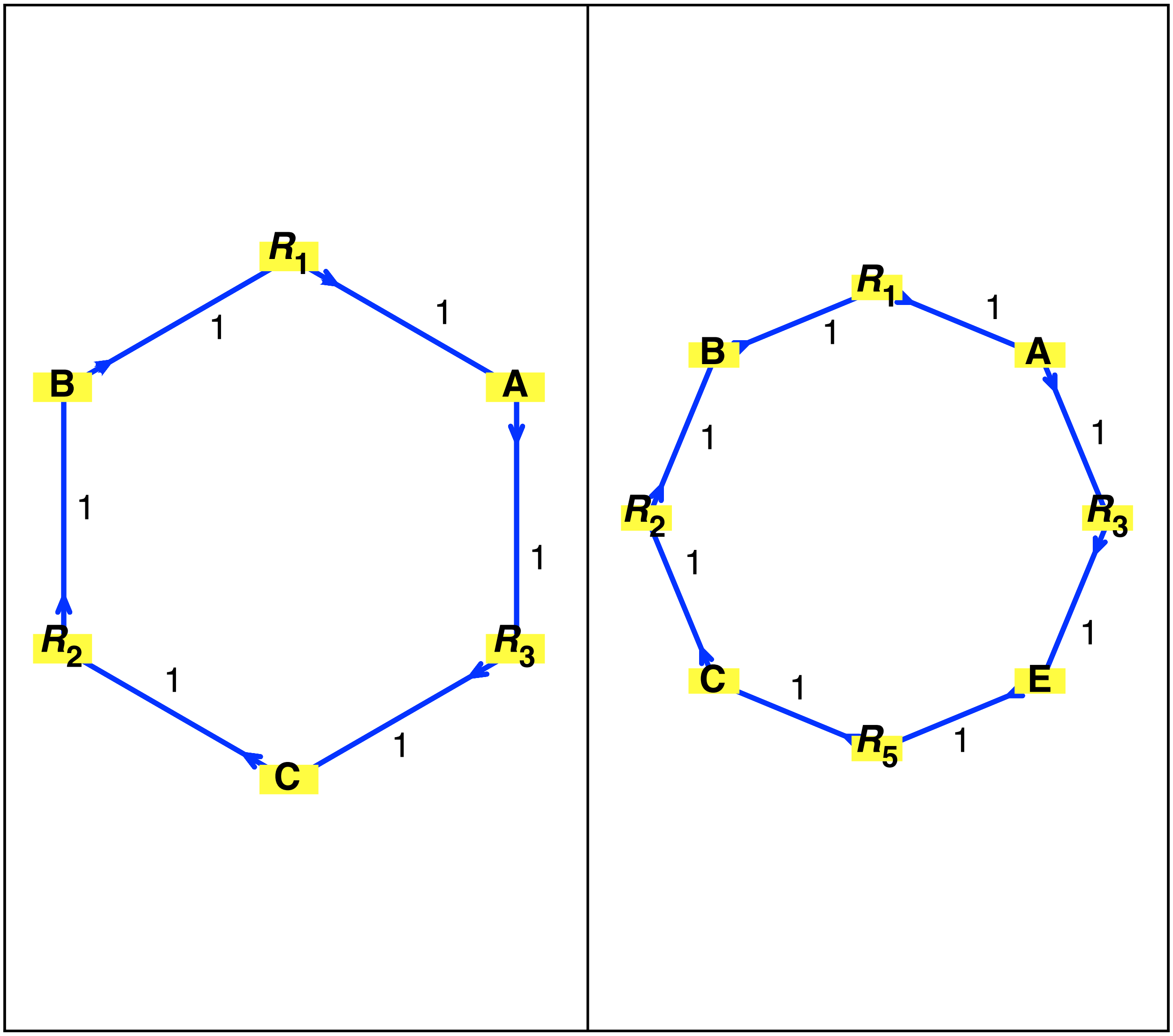
No. 15: injectiveEx3_1268.csv



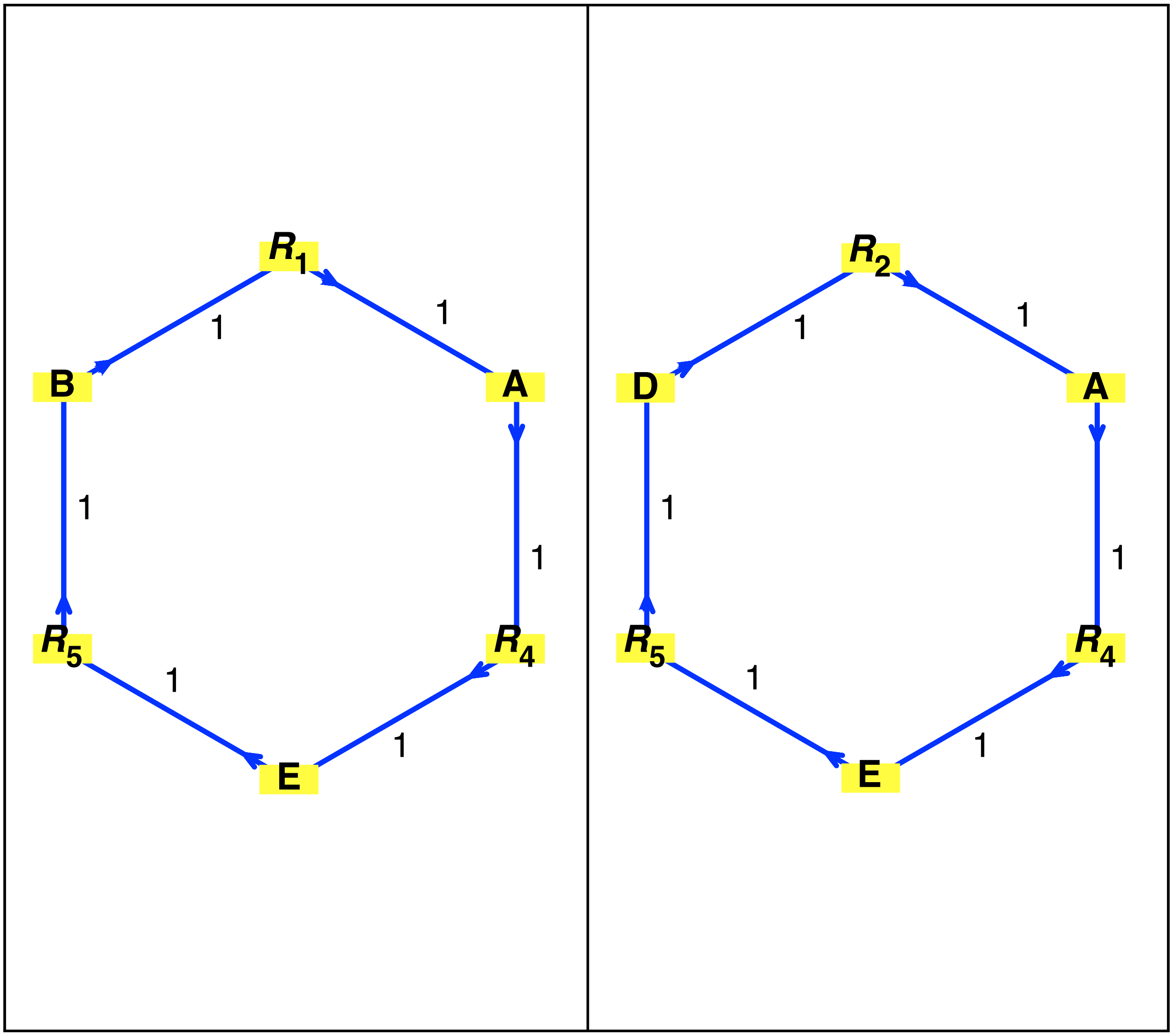
No. 16: injectiveEx3_1270.csv



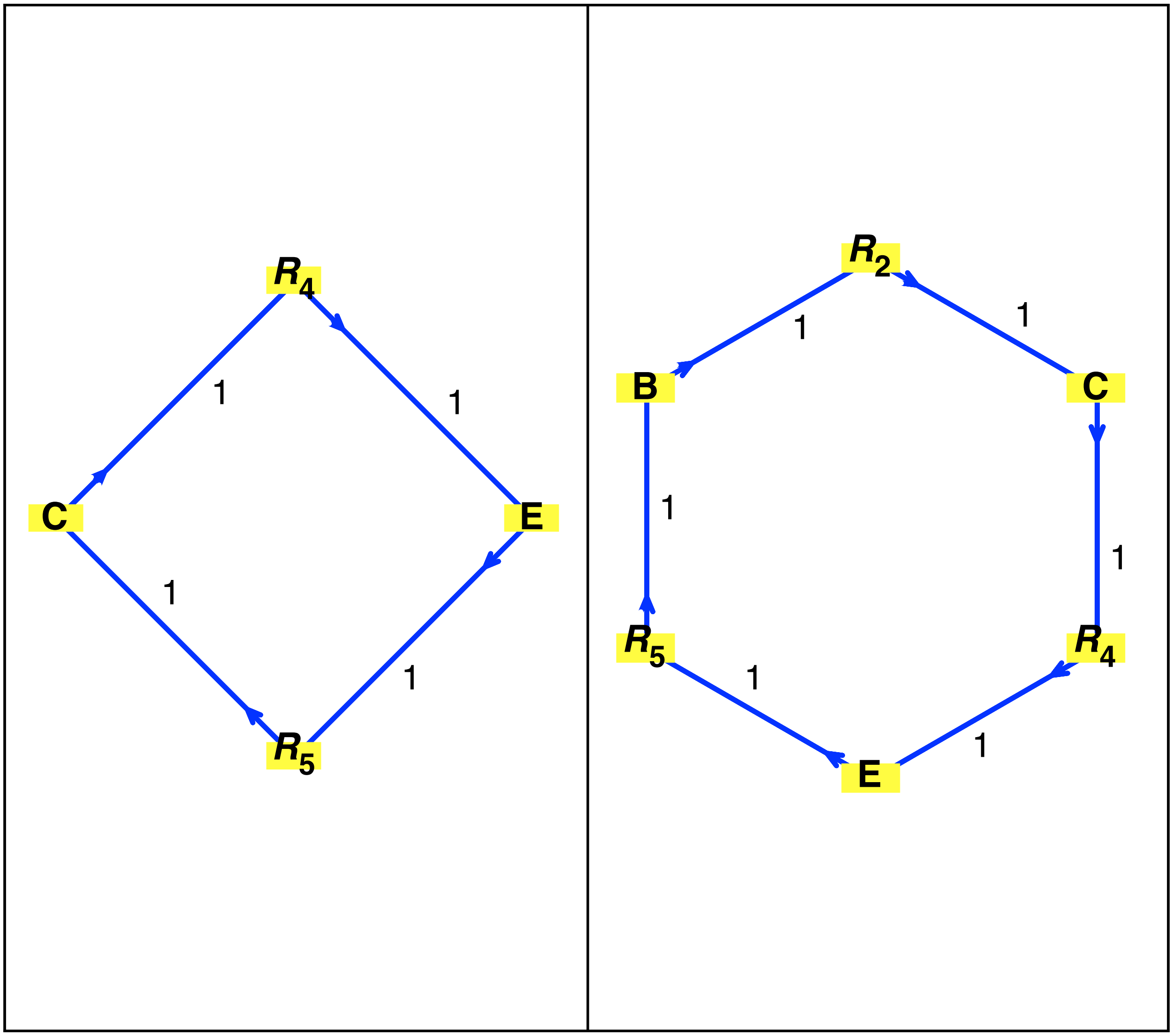
No. 17: injectiveEx3_1302.csv



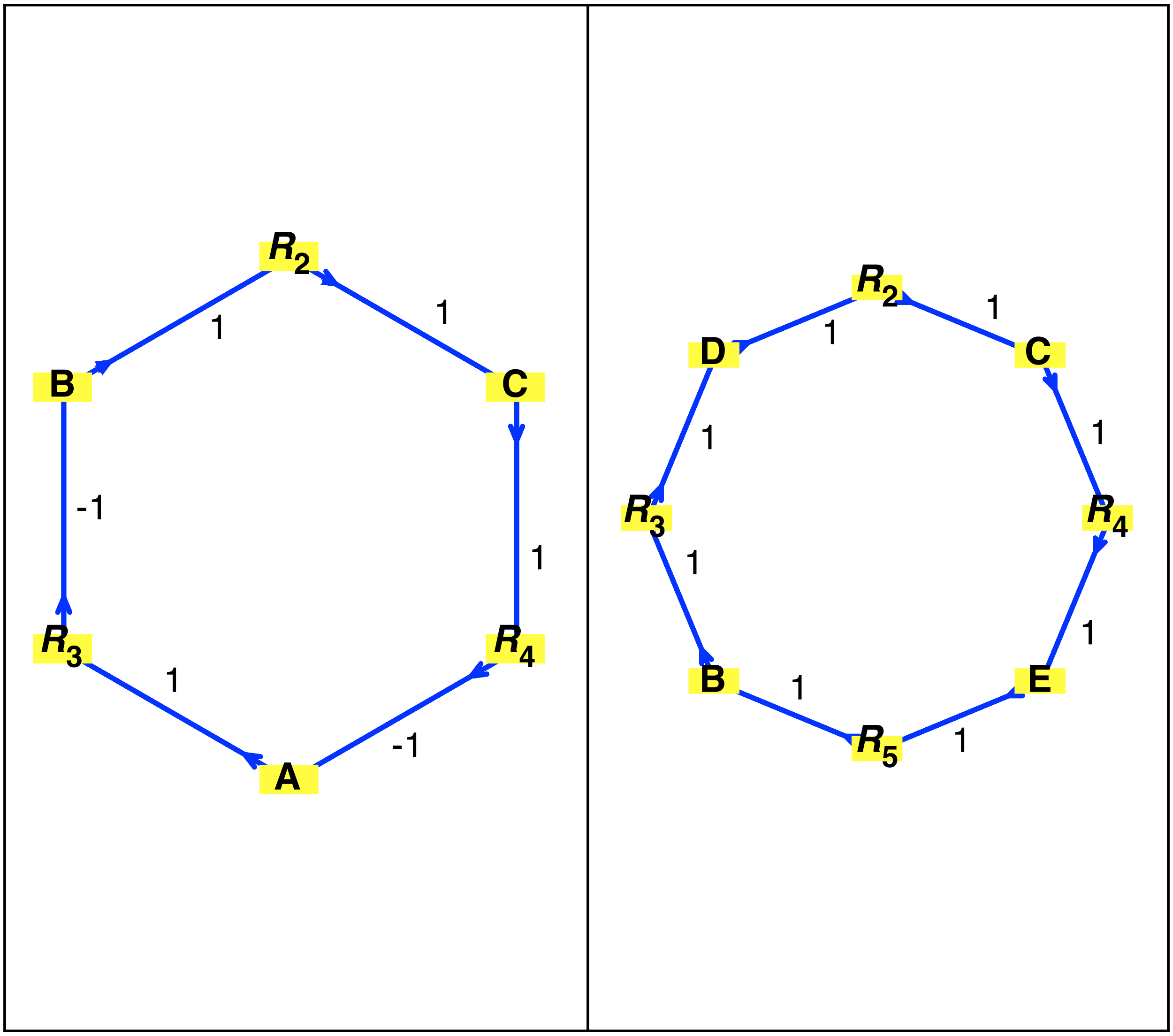
No. 18: injectiveEx3_1369.csv



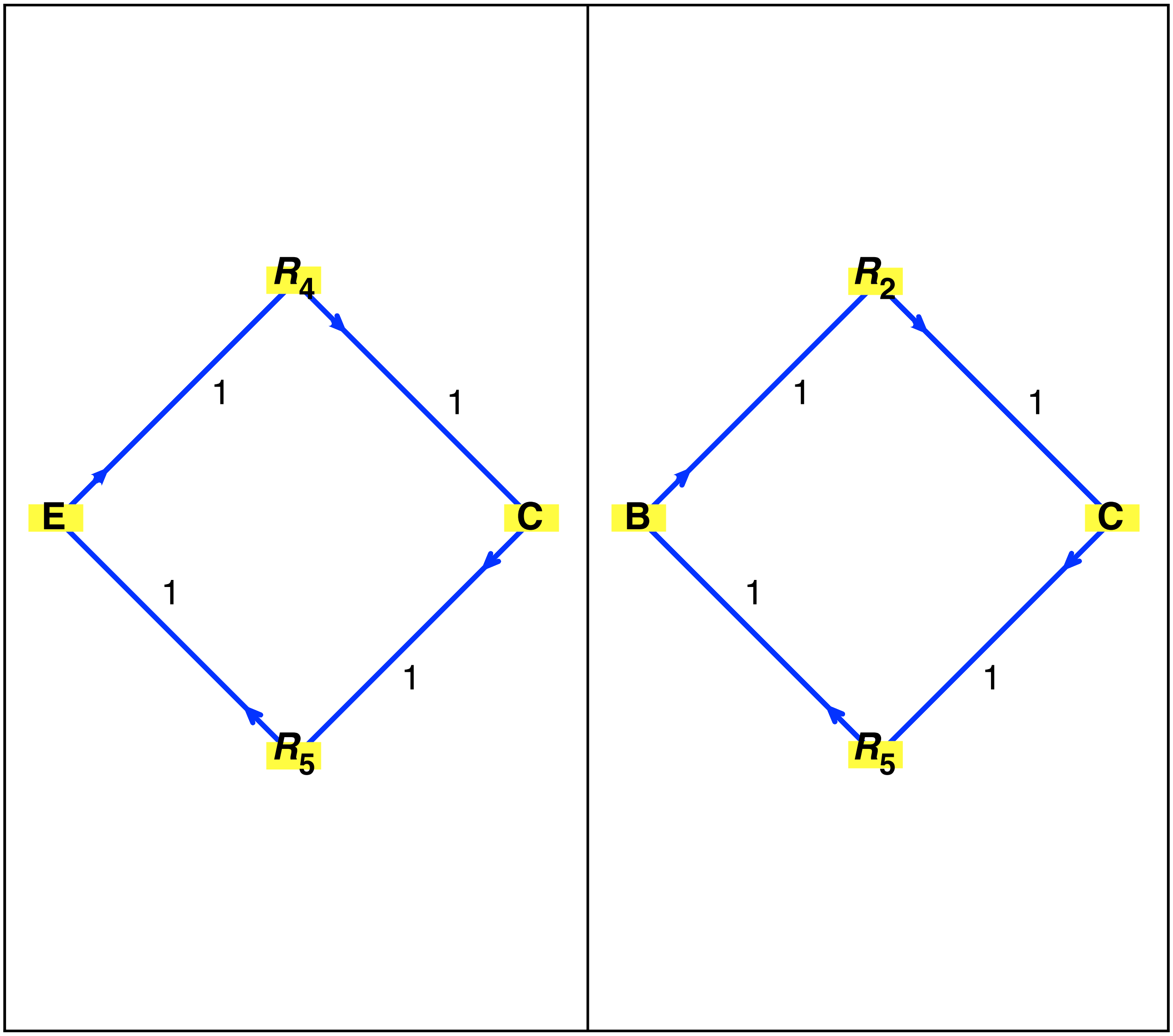
No. 19: injectiveEx3_1473.csv



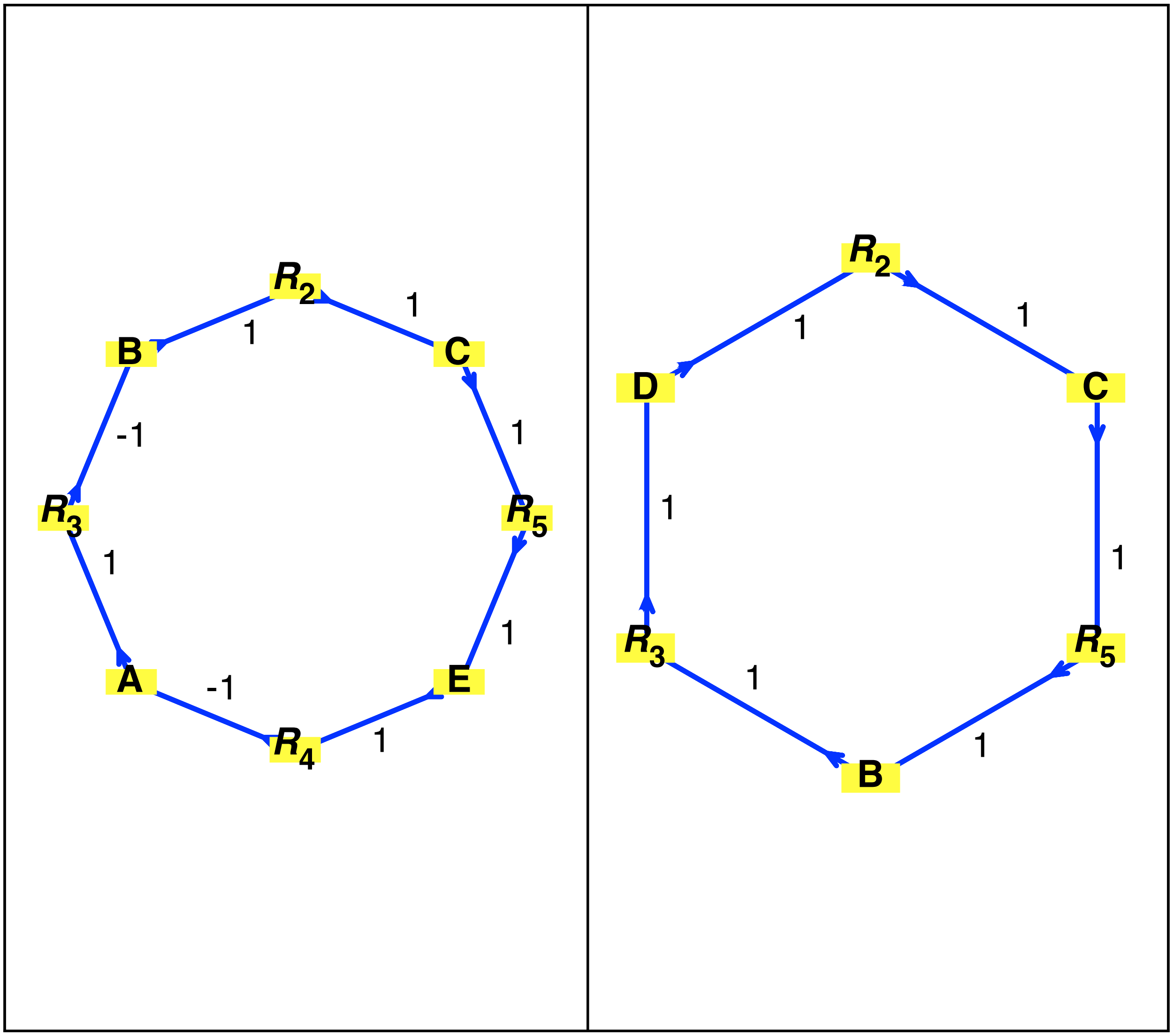
R4
C
E
R5
1
1
1
1
R2
B
C
R5
R4
E
1
1
1
1
1
1



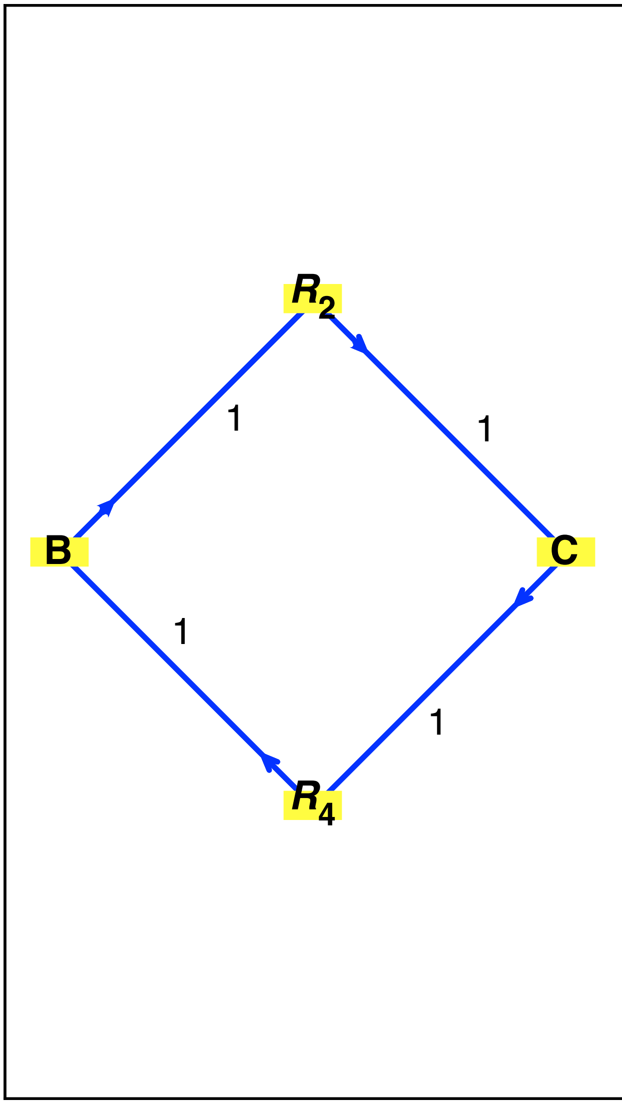
No. 20: injectiveEx3_1474.csv

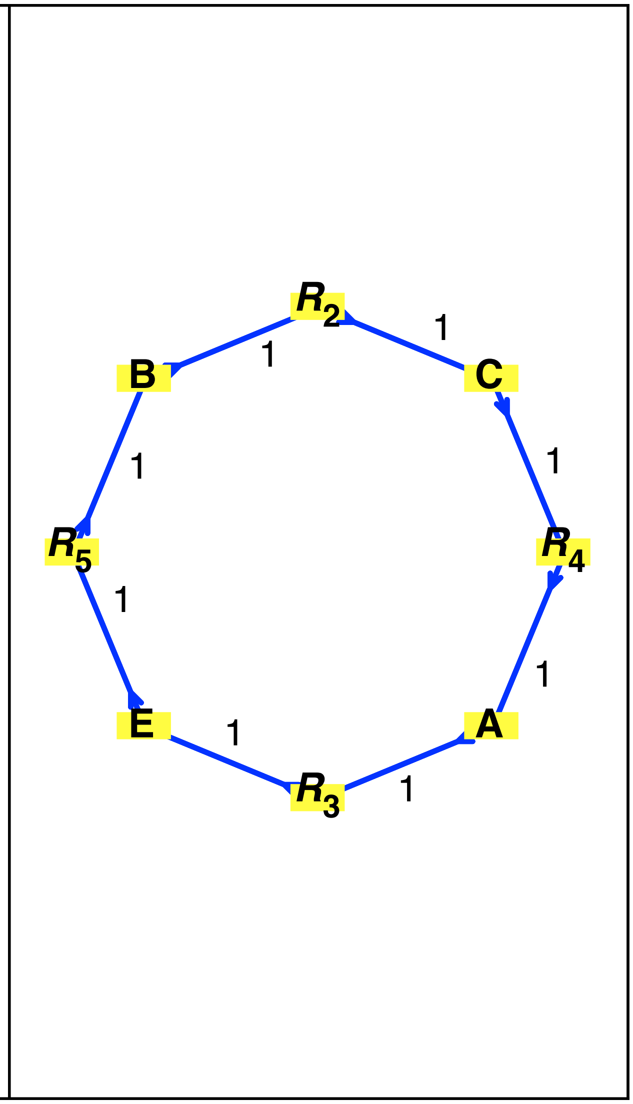


R4
E
C
R5
1
1
1
1
R2
B
C
R5
1
1
1
1

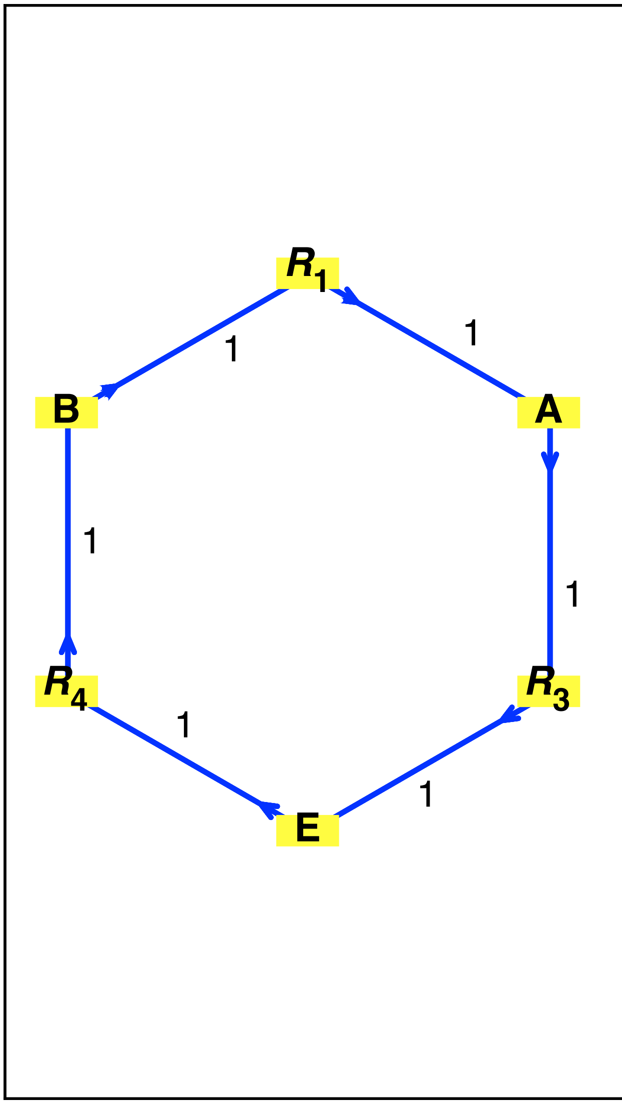


No. 21: injectiveEx3_1516.csv

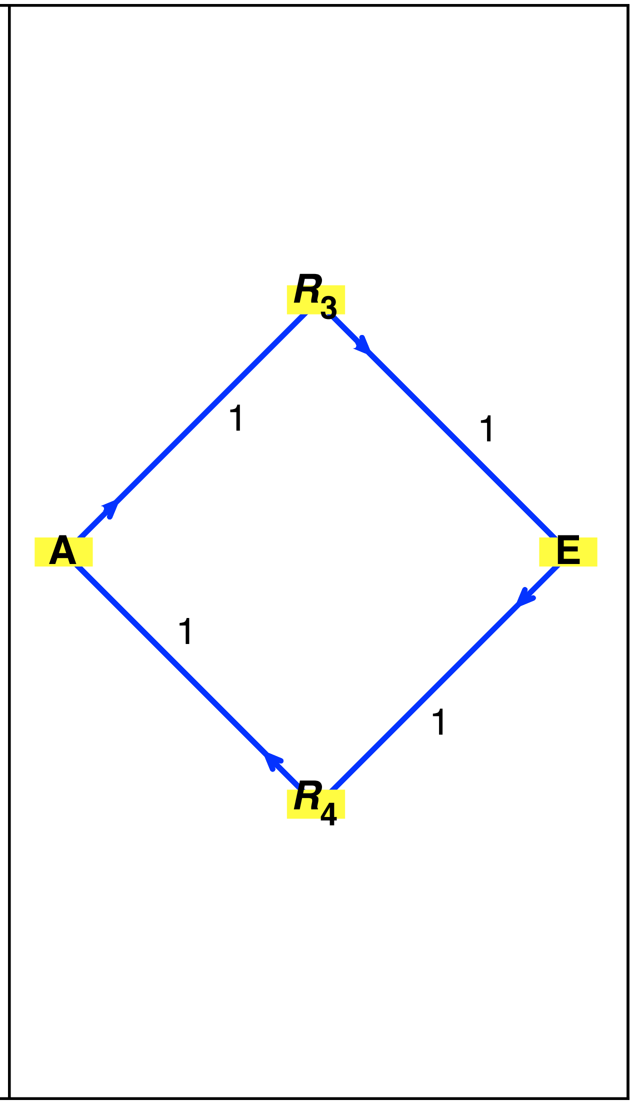




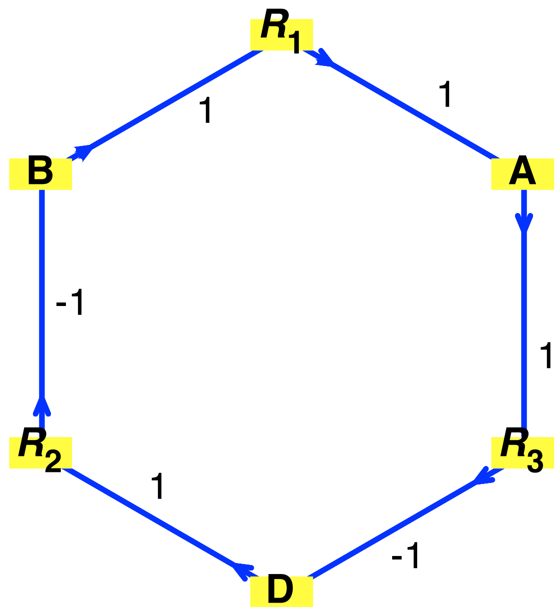
No. 22: injectiveEx3_1518.csv



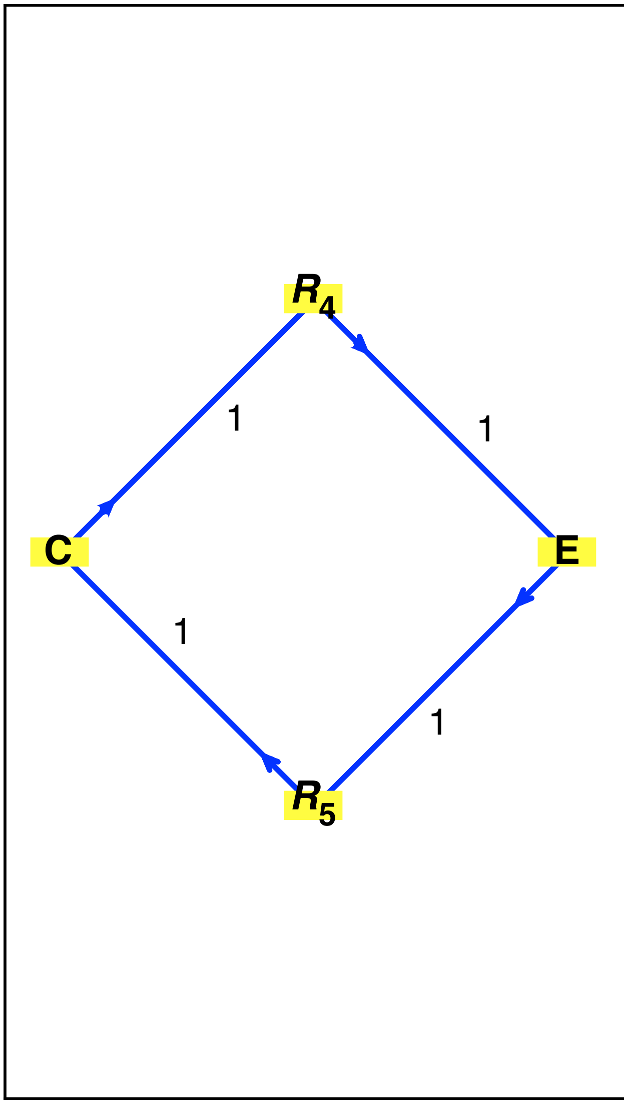
R_1
B
A
R_4
R_3
E
1
1
1
1
1
1

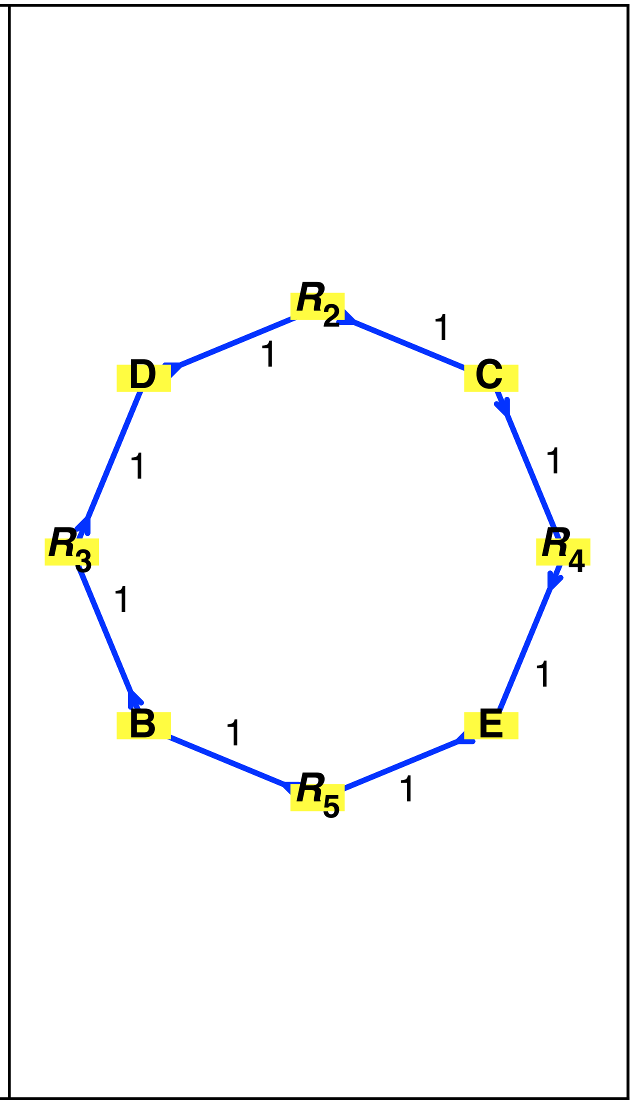


R_3
A
E
R_4
1
1
1
1

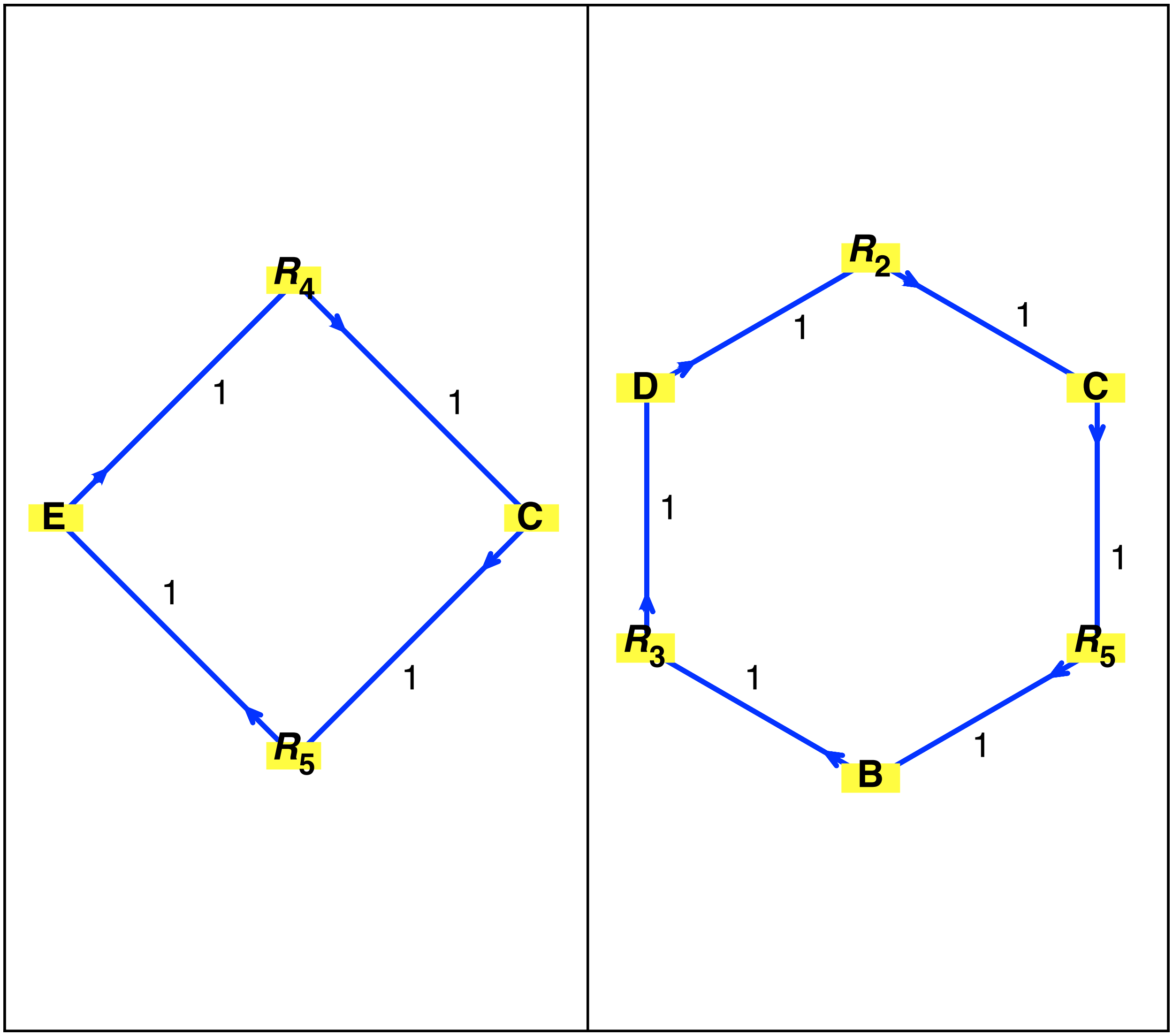


No. 23: injectiveEx3_1721.csv

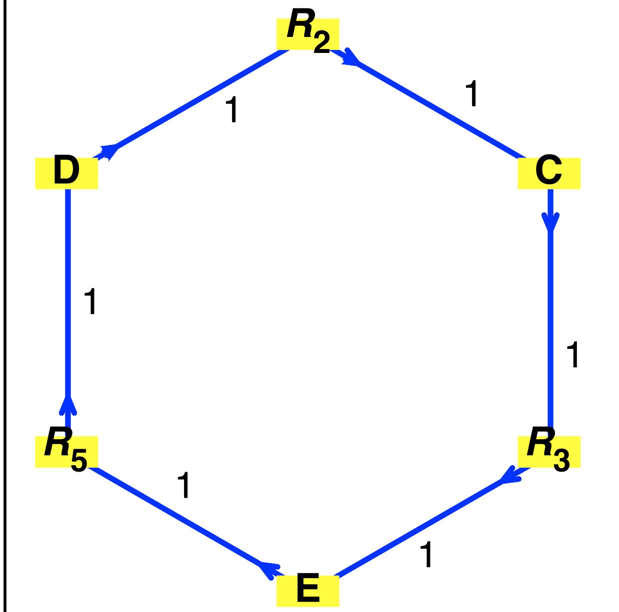


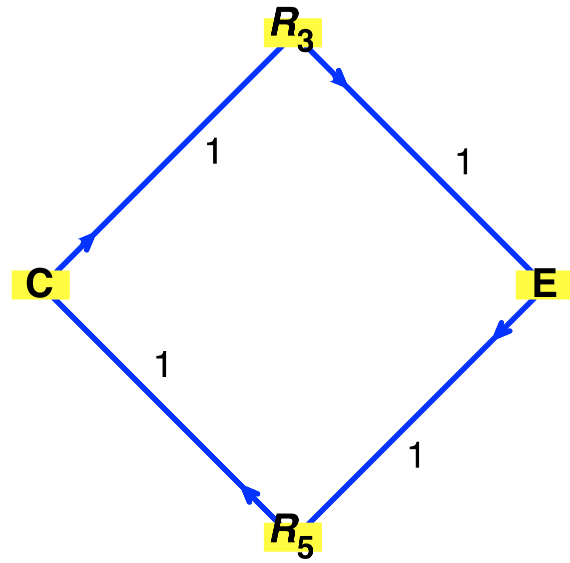


No. 24: injectiveEx3_1722.csv

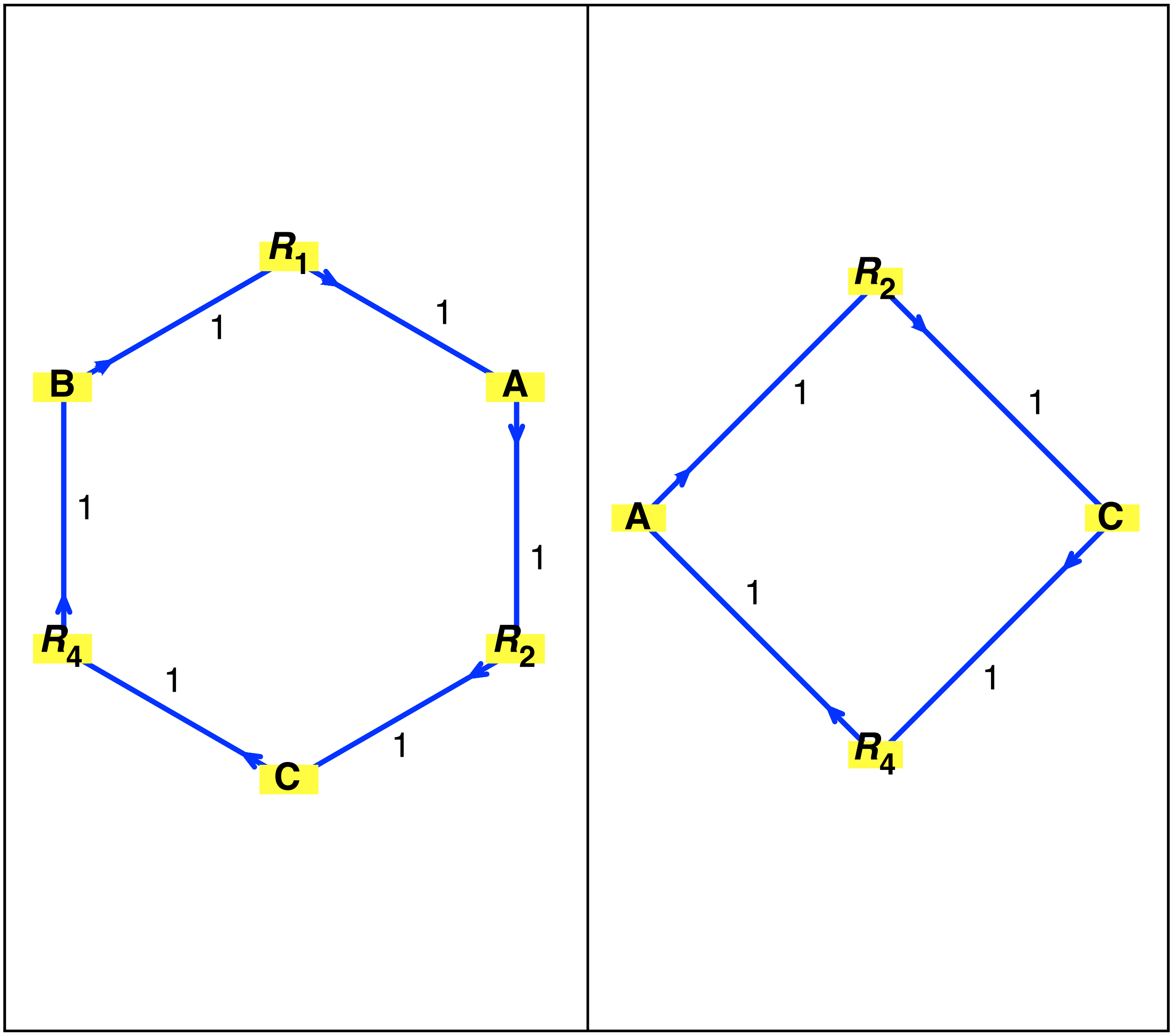


No. 25: injectiveEx3_1743.csv

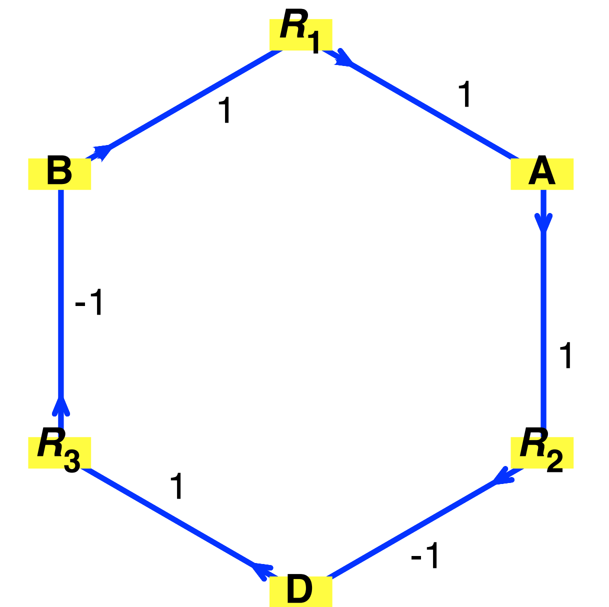


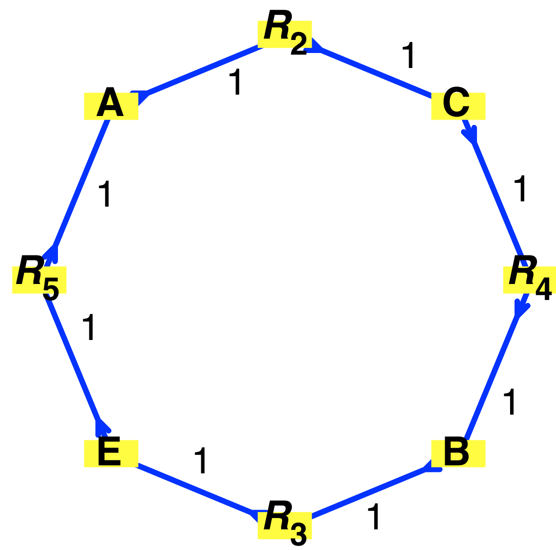


No. 26: injectiveEx3_1796.csv

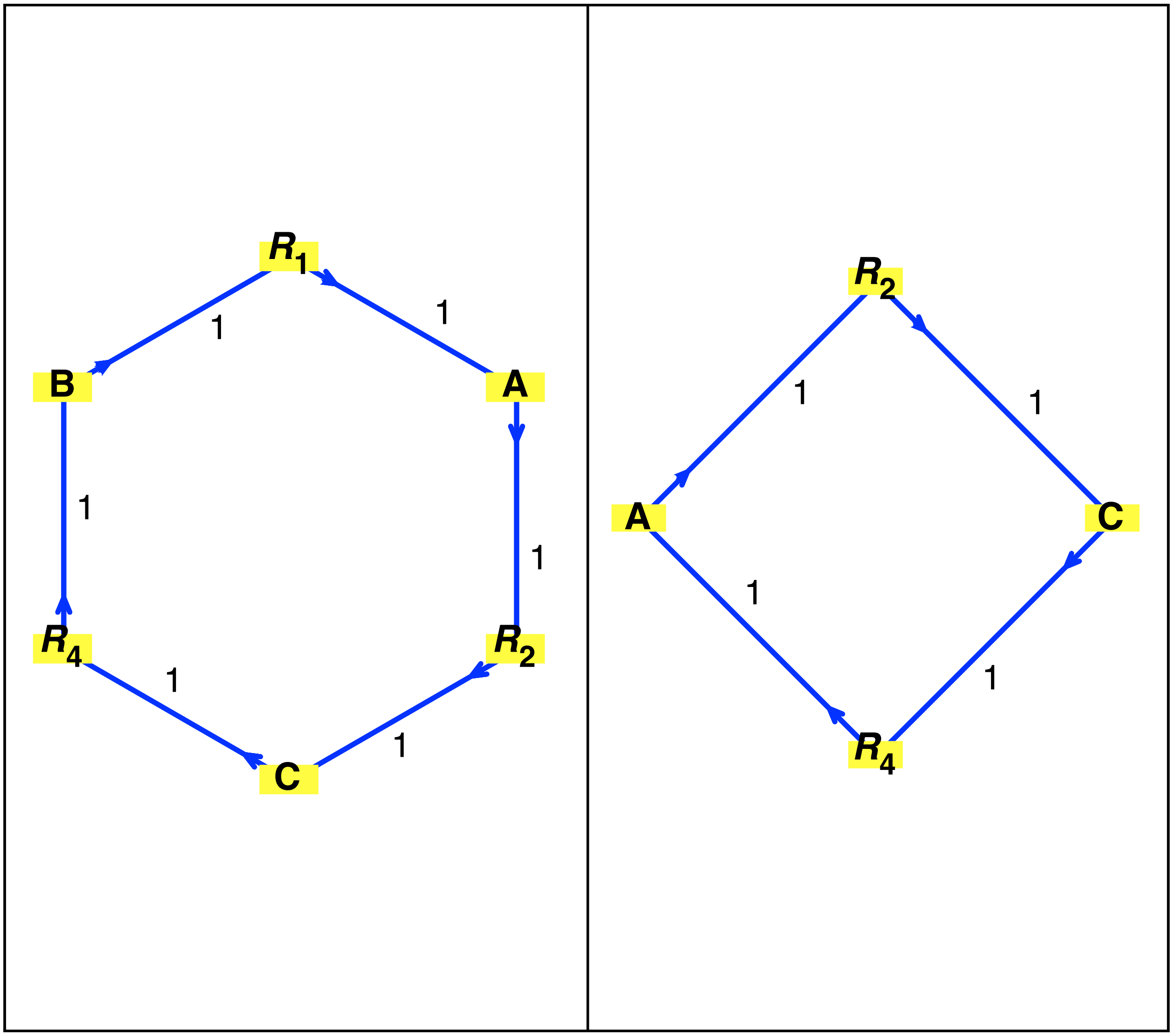


R_1
1
1
B
A
1
1
R_4
R_2
1
1
C
R_2
1
1
A
C
1
1
R_4

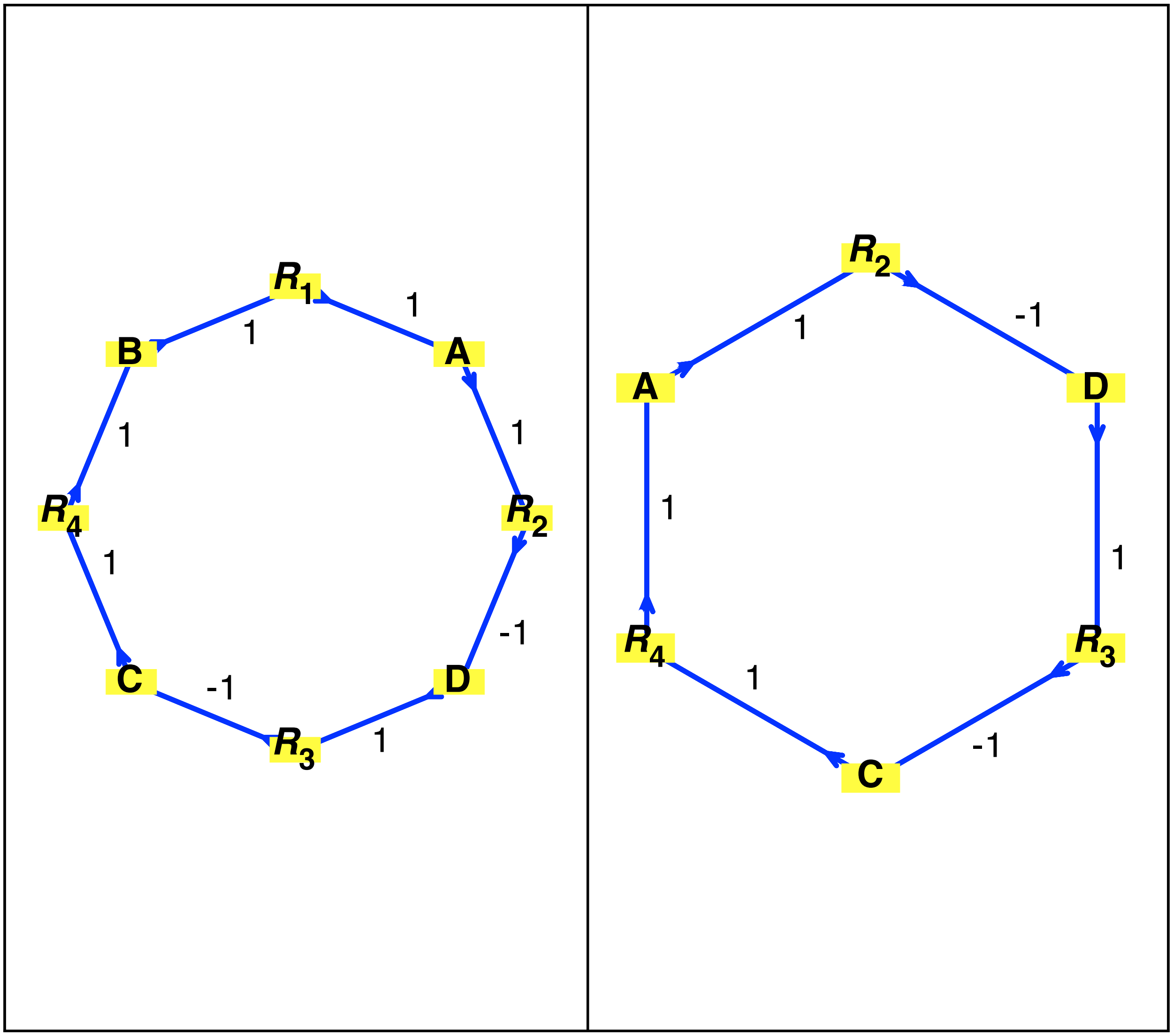




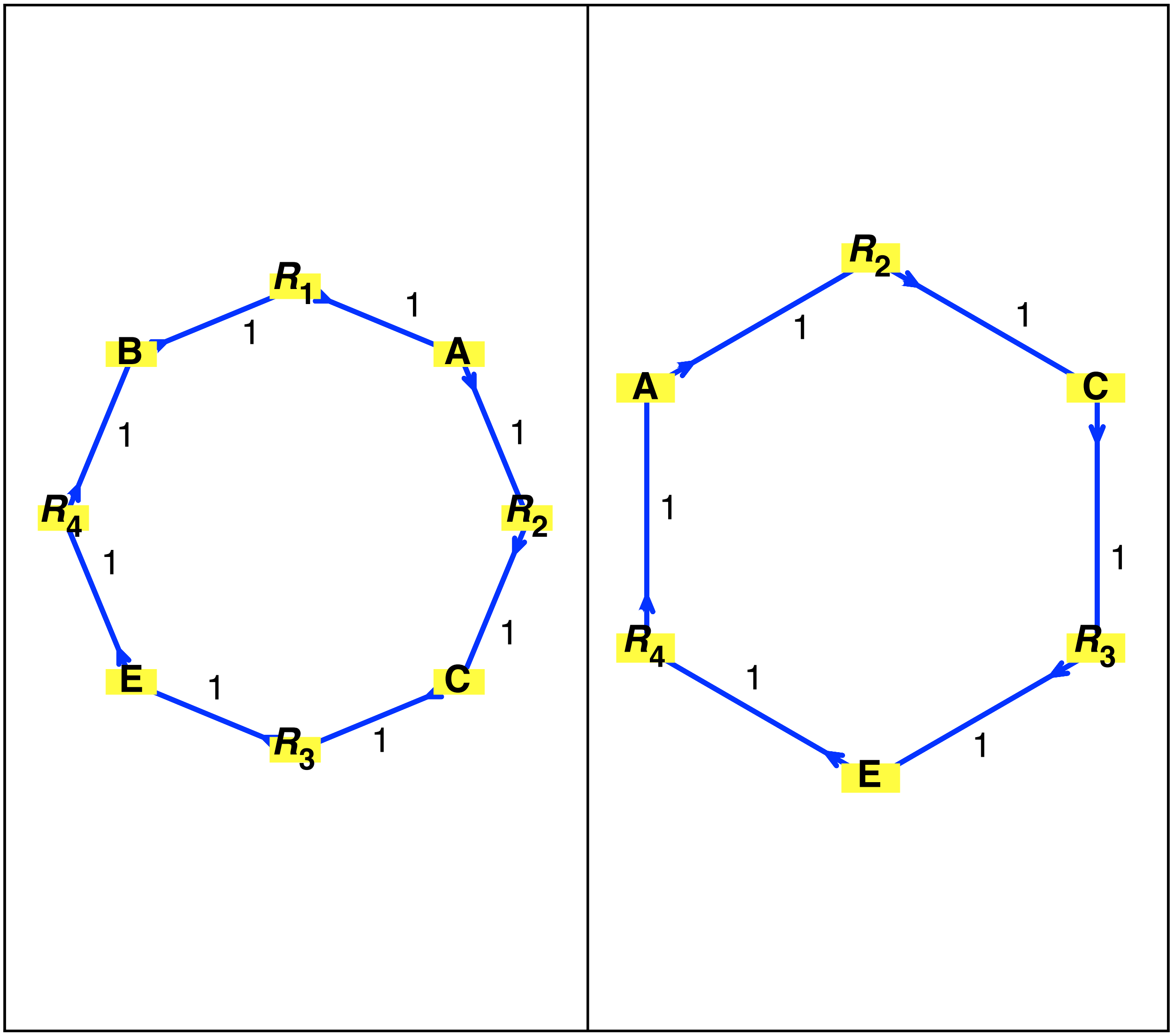
No. 27: injectiveEx3_1814.csv



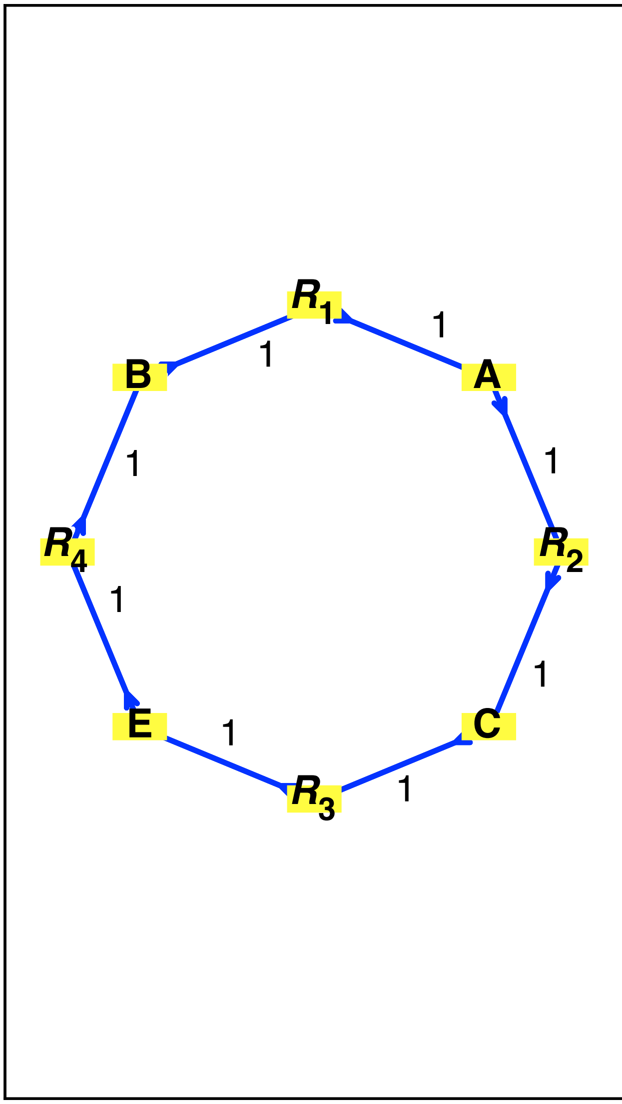
R1
1
1
B
A
1
1
R4
R2
1
1
C
R2
1
1
A
C
1
1
R4

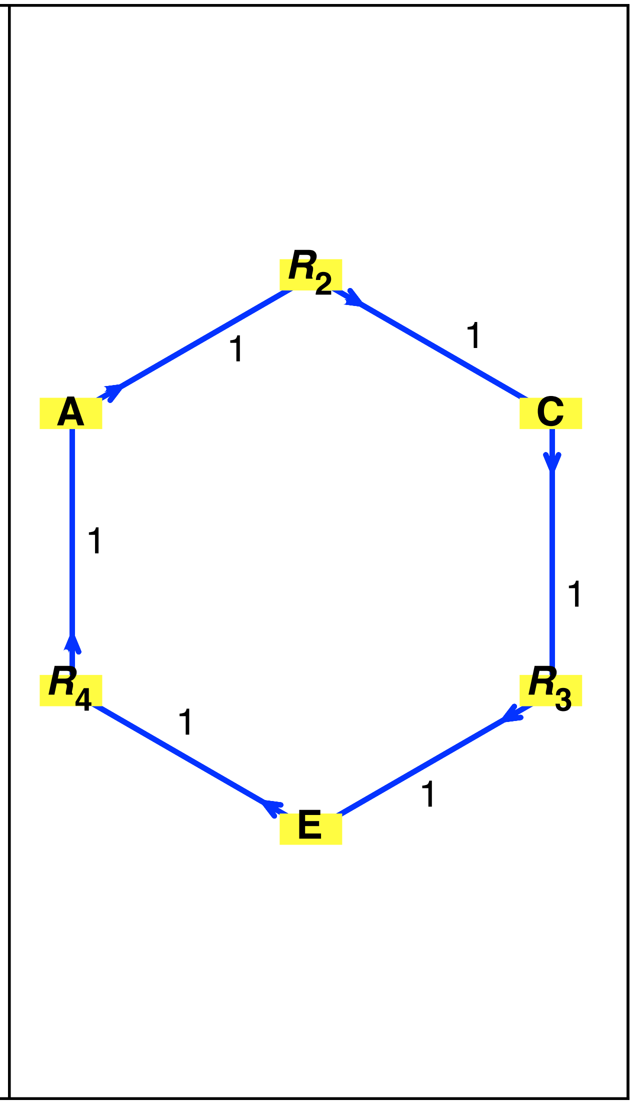


No. 28: injectiveEx3_1816.csv

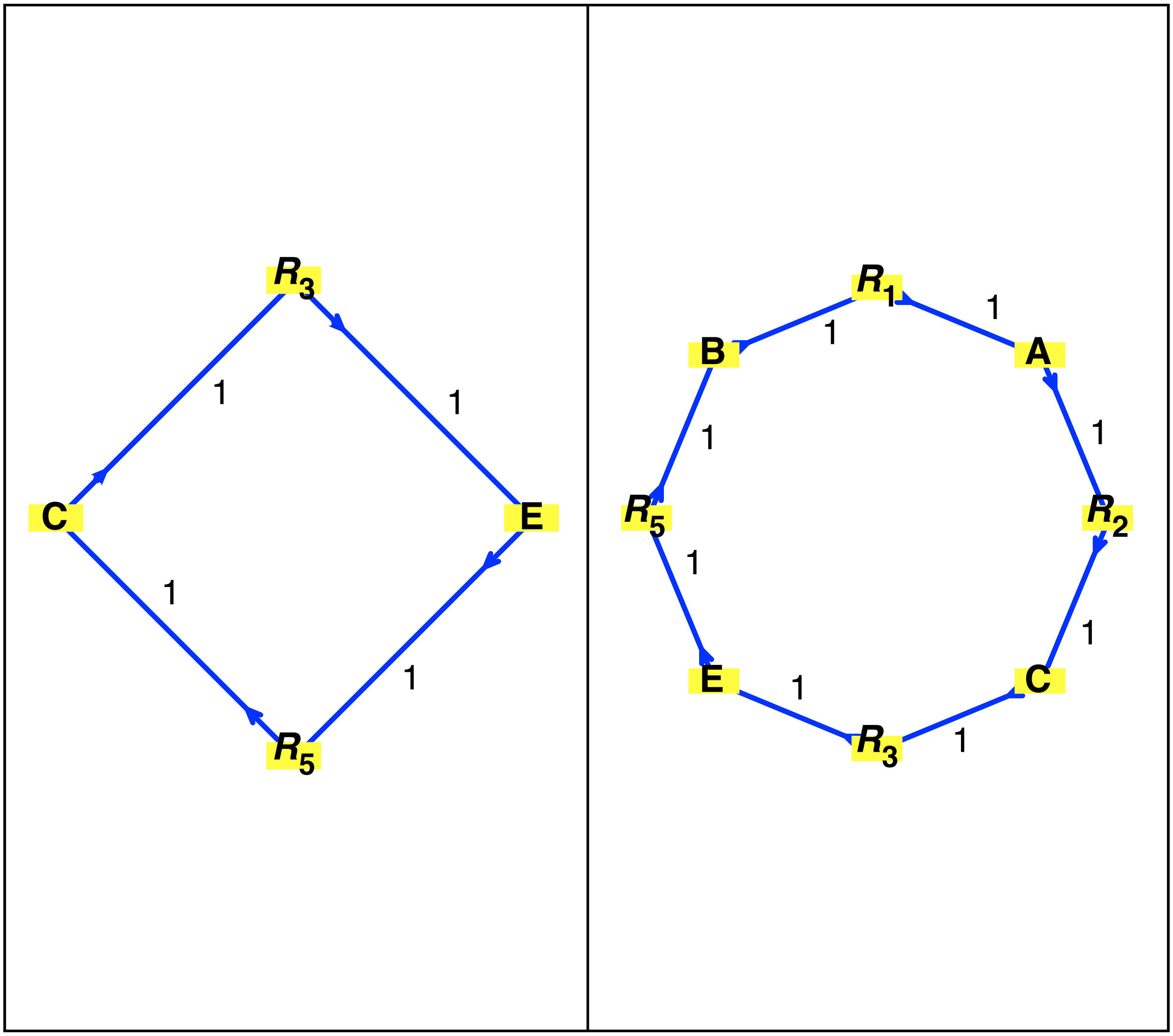


No. 29: injectiveEx3_1817.csv

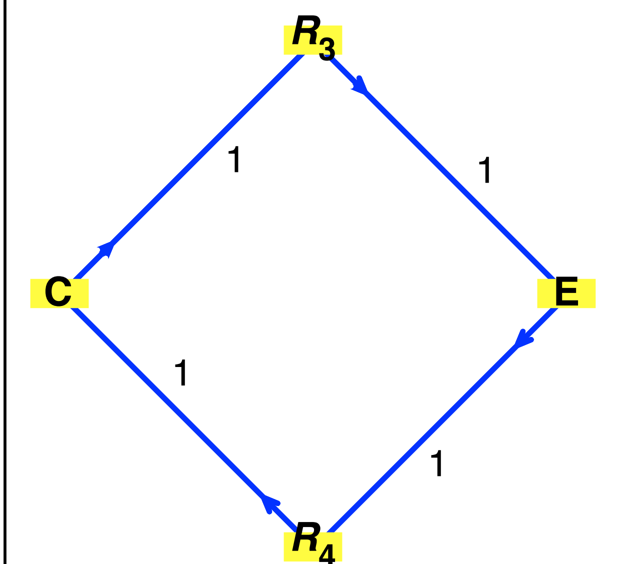


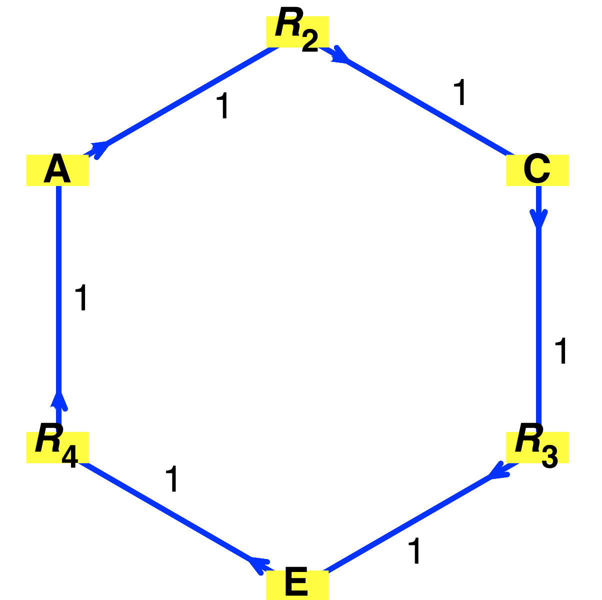


No. 30: injectiveEx3_1819.csv

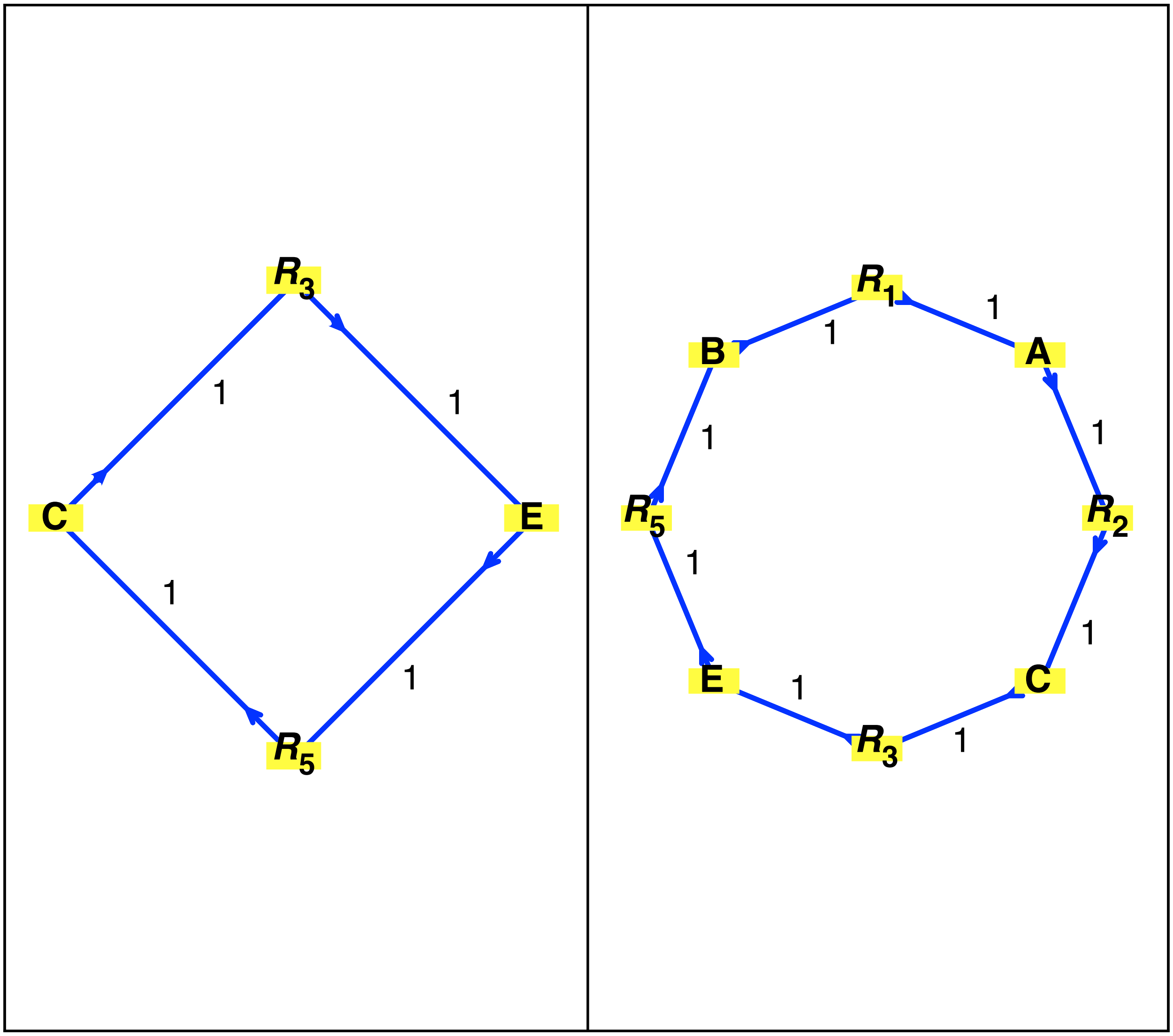


No. 31: injectiveEx3_1820.csv

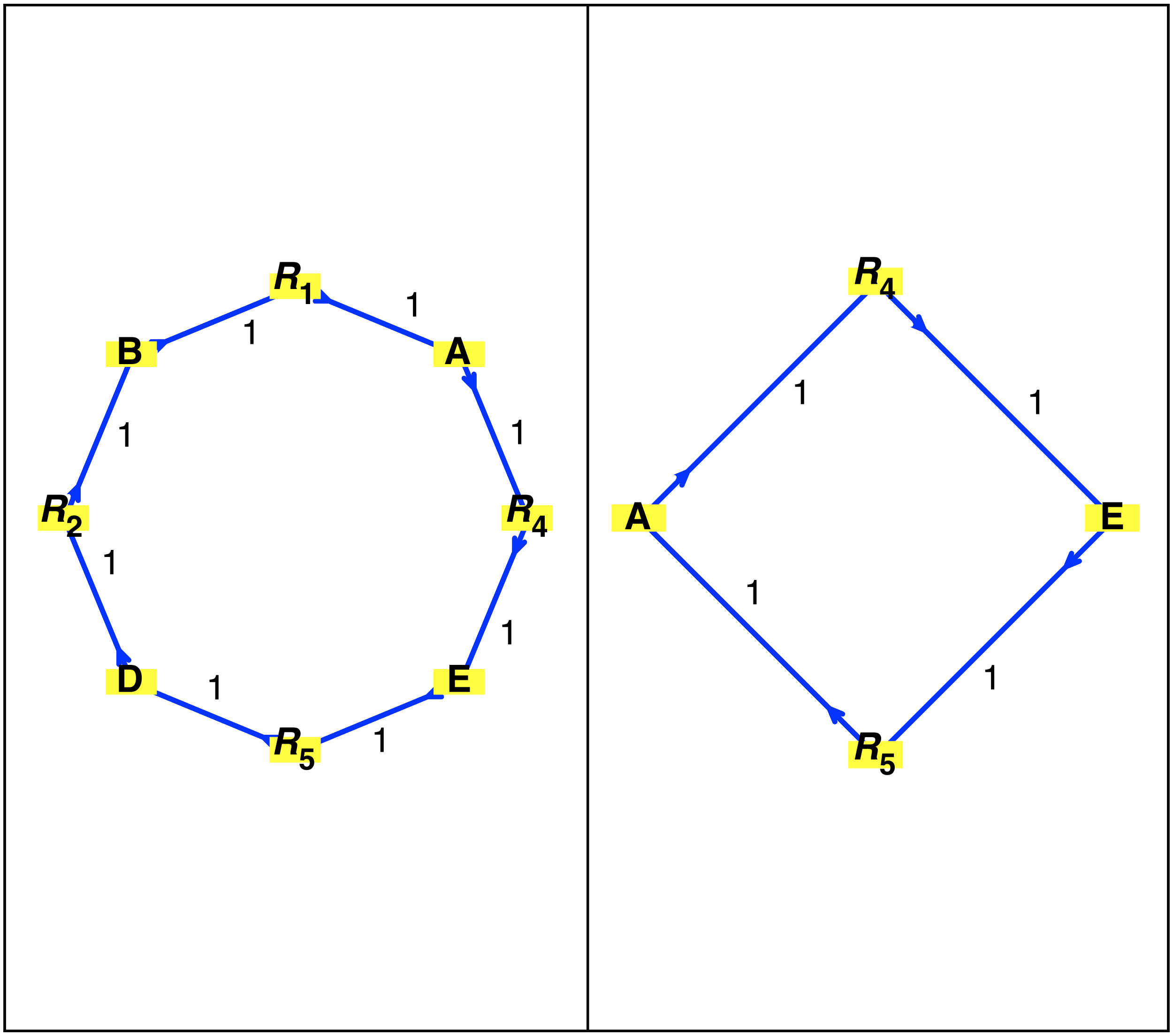




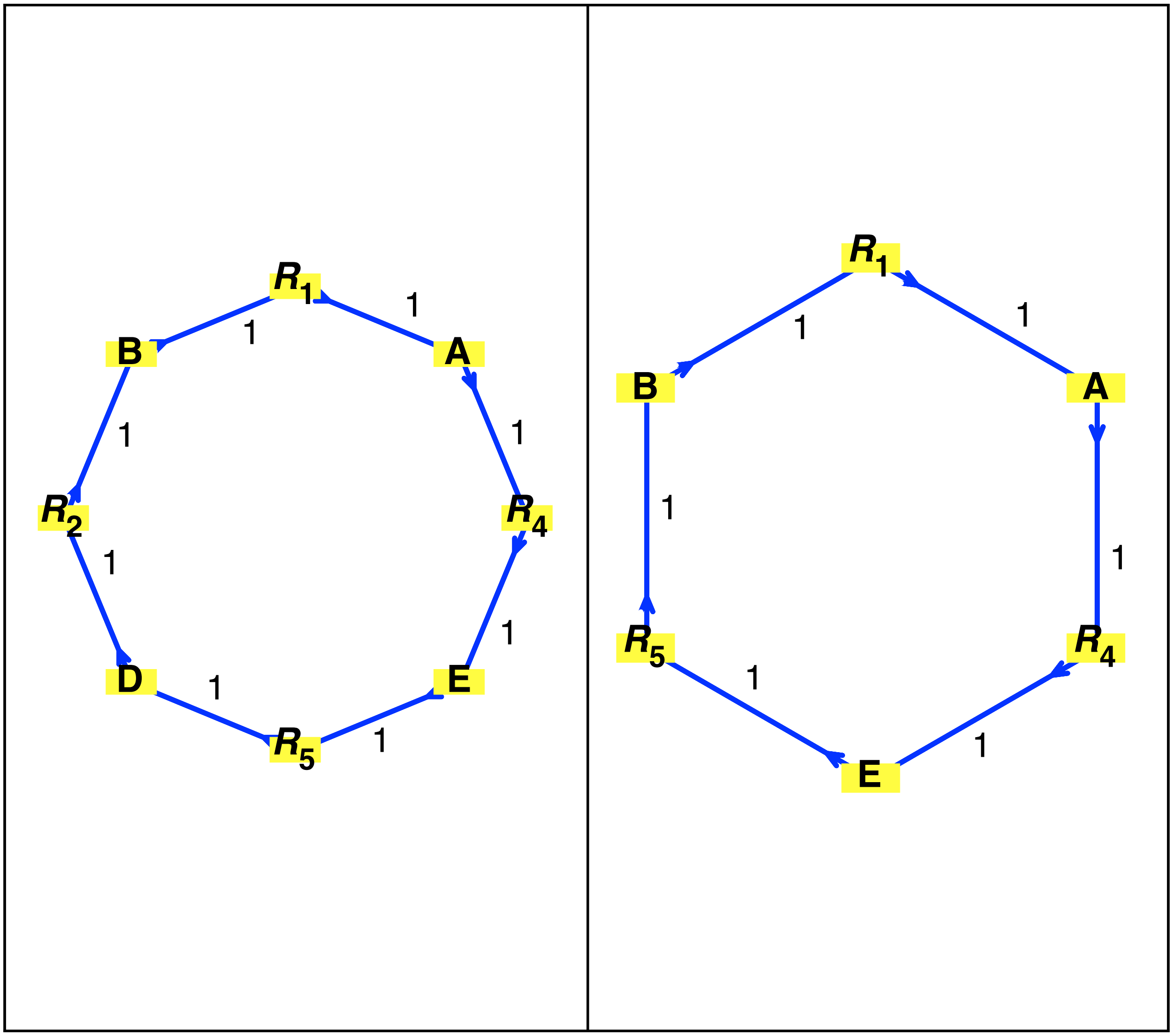
No. 32: injectiveEx3_1821.csv



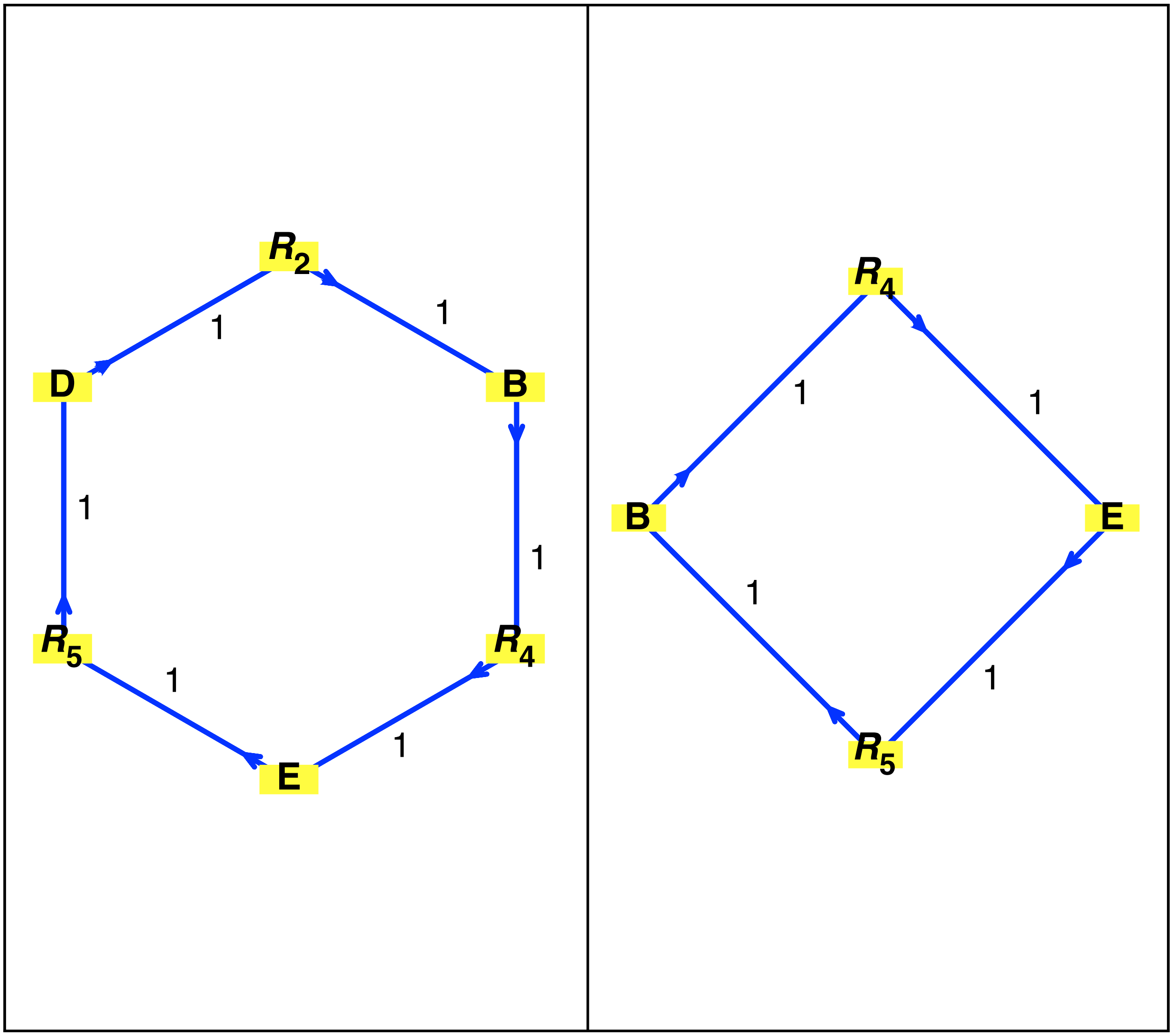
No. 33: injectiveEx3_2945.csv



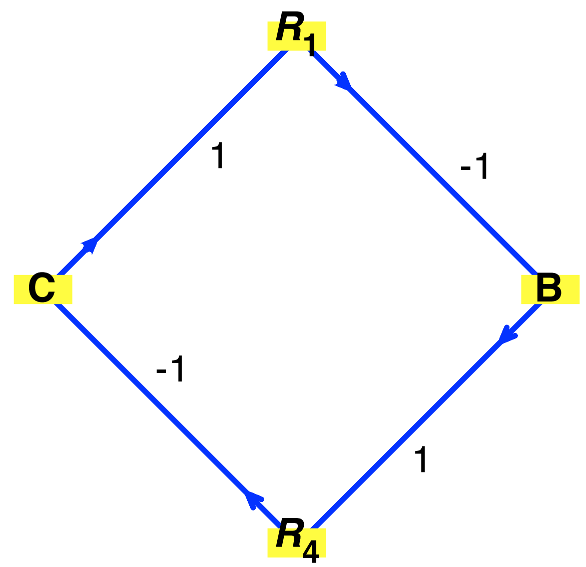
No. 34: injectiveEx3_2946.csv

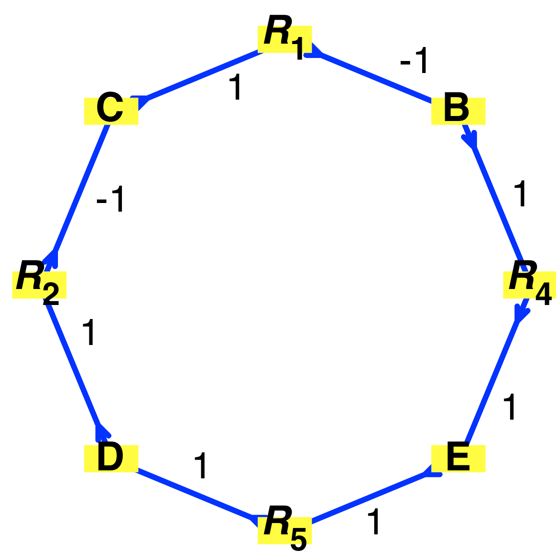


No. 35: injectiveEx3_2954.csv

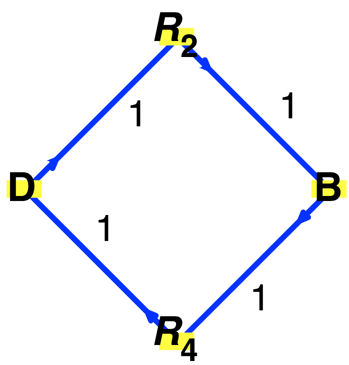
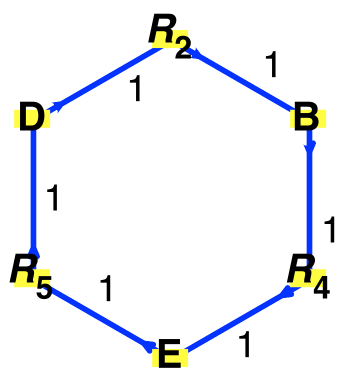
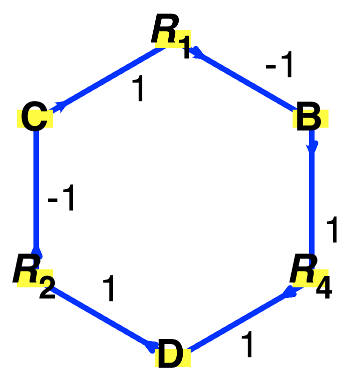


R2
D
B
R5
R4
E
1
1
1
1
1
1
R4
B
E
R5
1
1
1
1





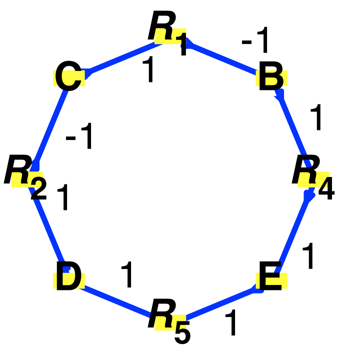
No. 36: injectiveEx3_2955.csv

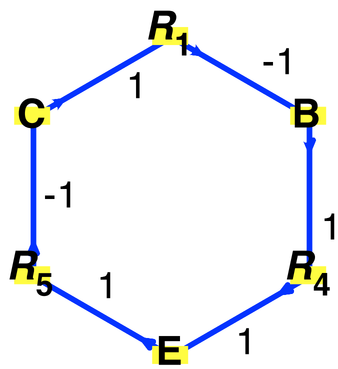
		

R_2
1
1
D
B
1
1
R_4

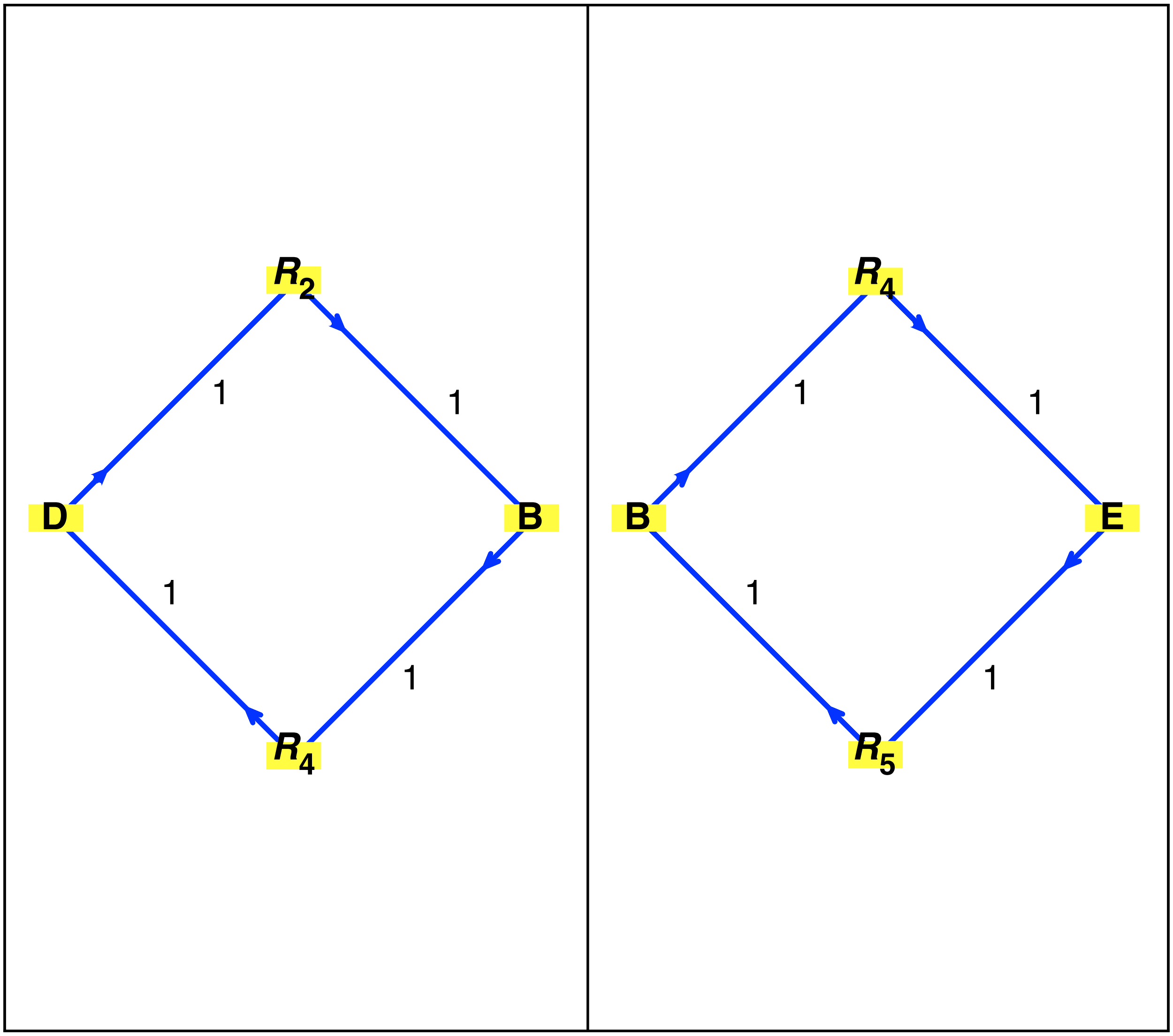
R_2
1
1
D
B
1
1
R_5
1
R_4
E
1

R_1
-1
1
C
B
-1
1
R_2
1
R_4
D
1

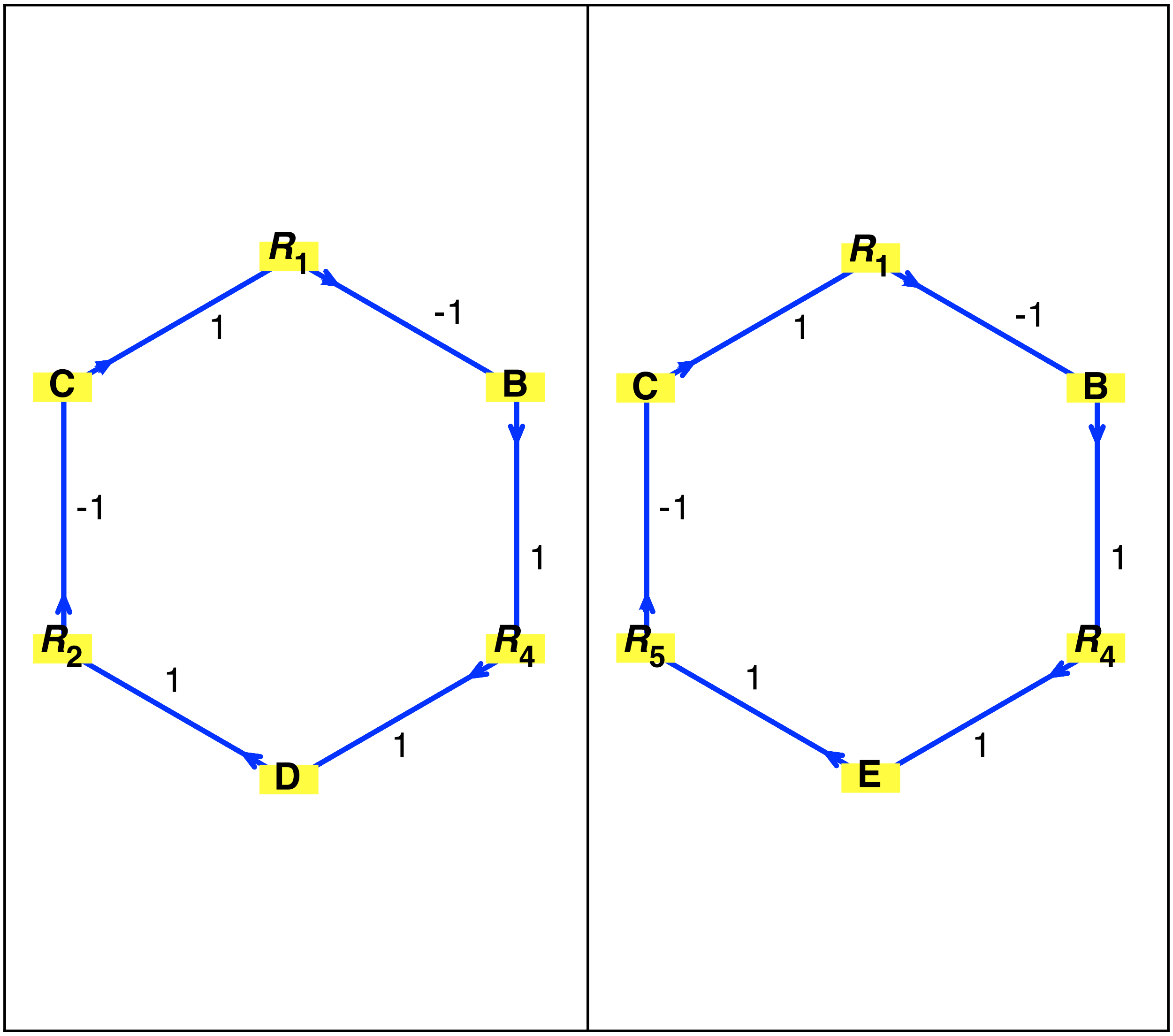




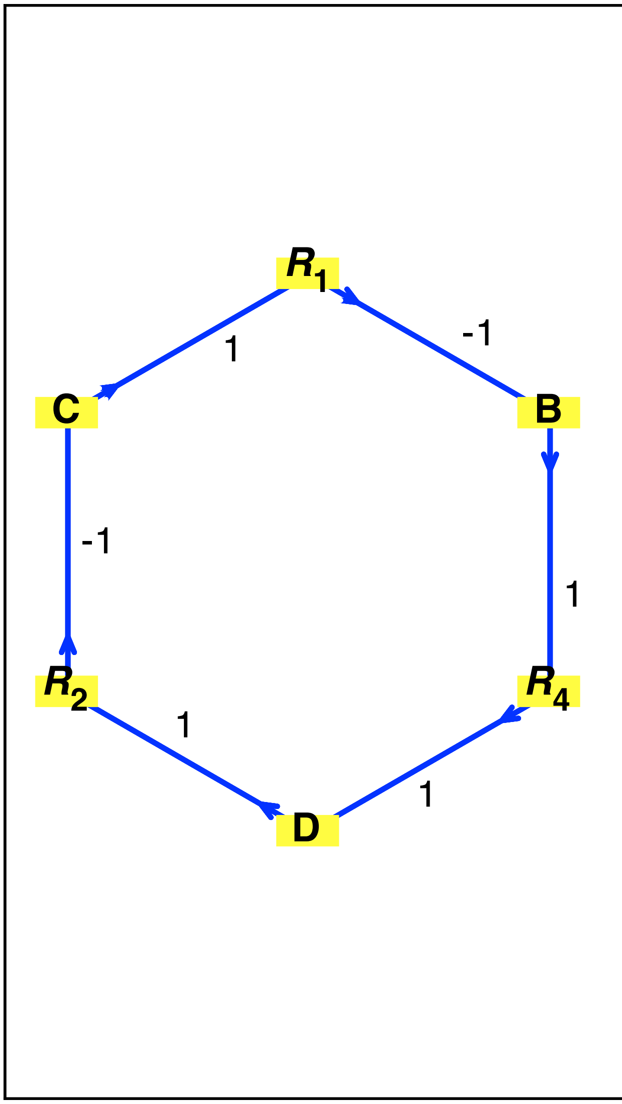
No. 37: injectiveEx3_2957.csv

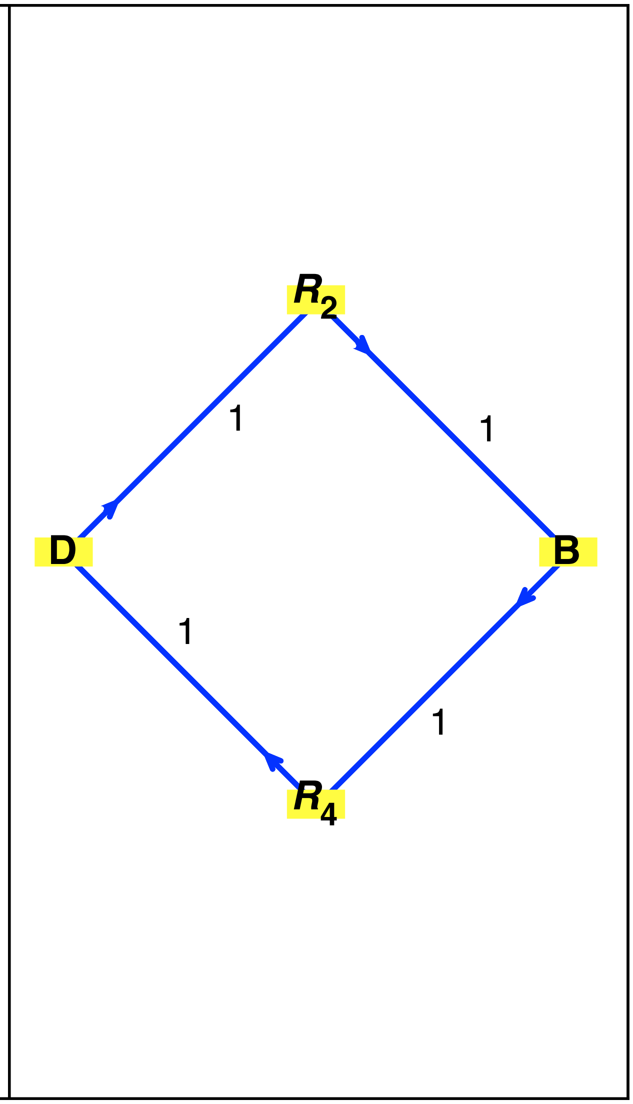


R2
D
B
R4
1
1
1
1
R4
B
E
R5
1
1
1
1

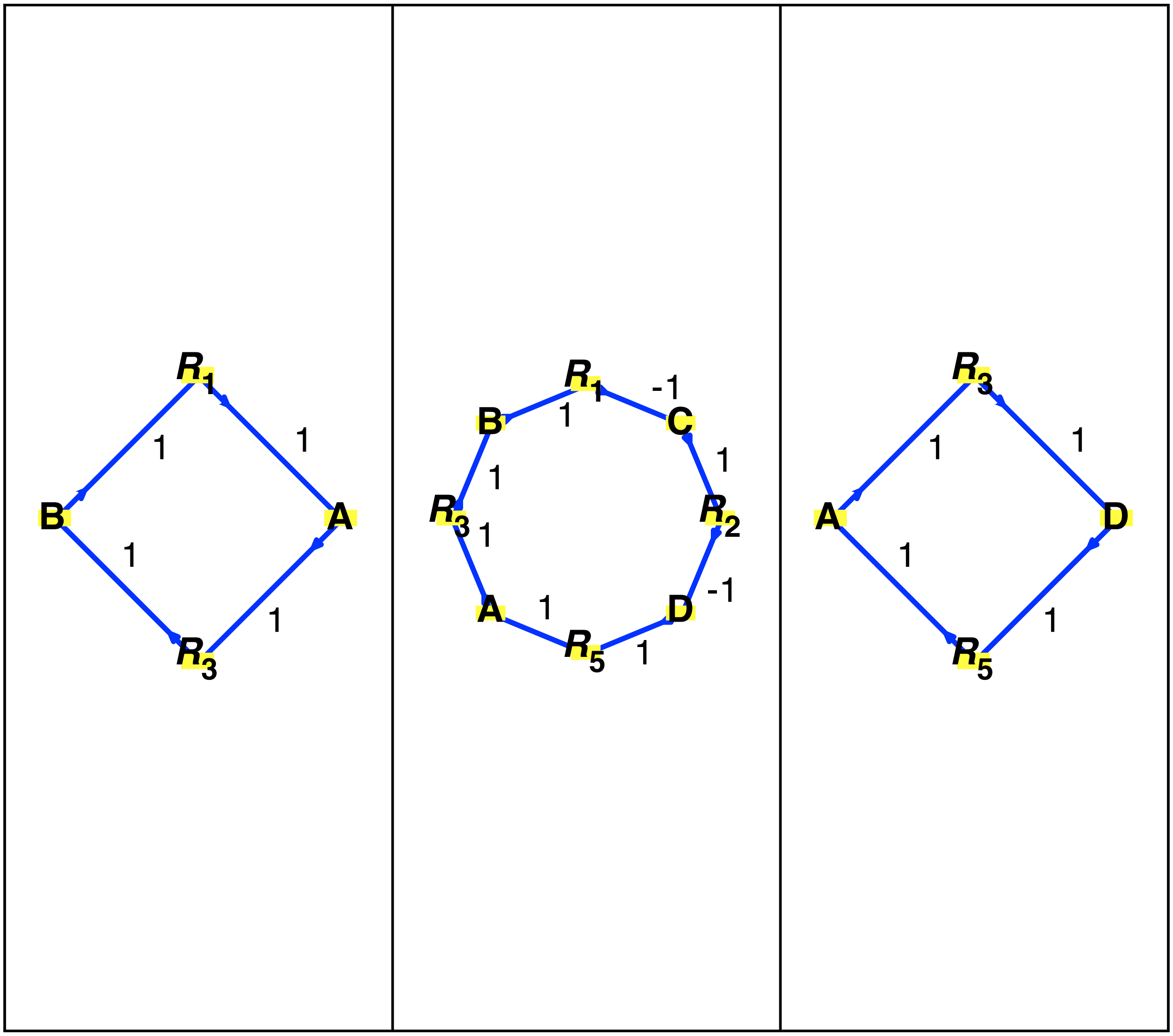


No. 38: injectiveEx3_2958.csv

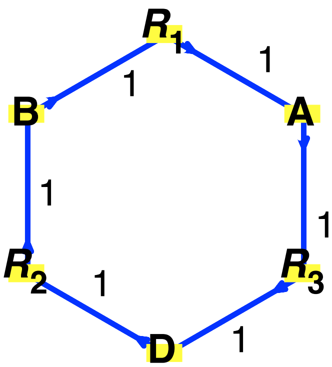
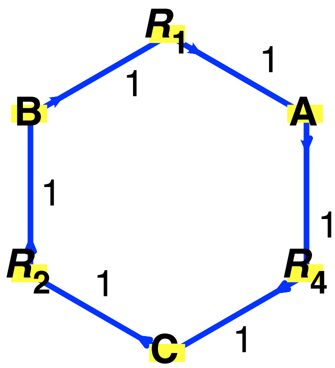
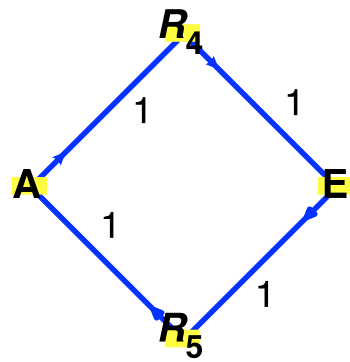


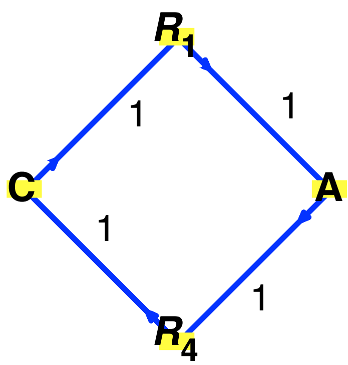
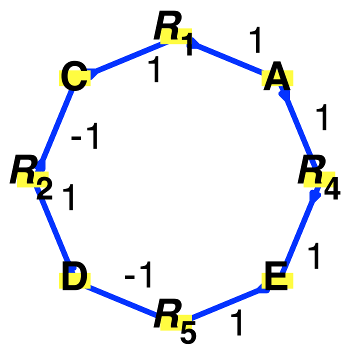


No. 39: injectiveEx3_2965.csv

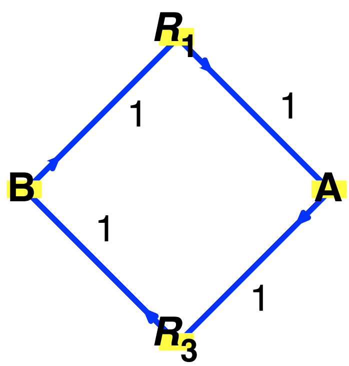
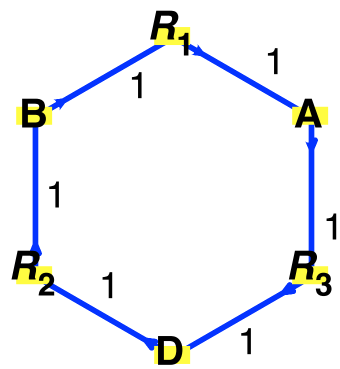
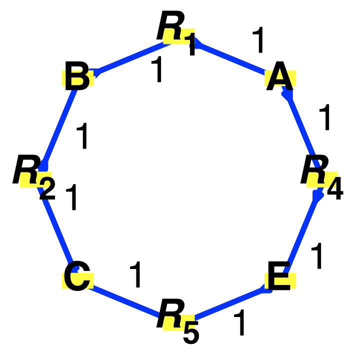


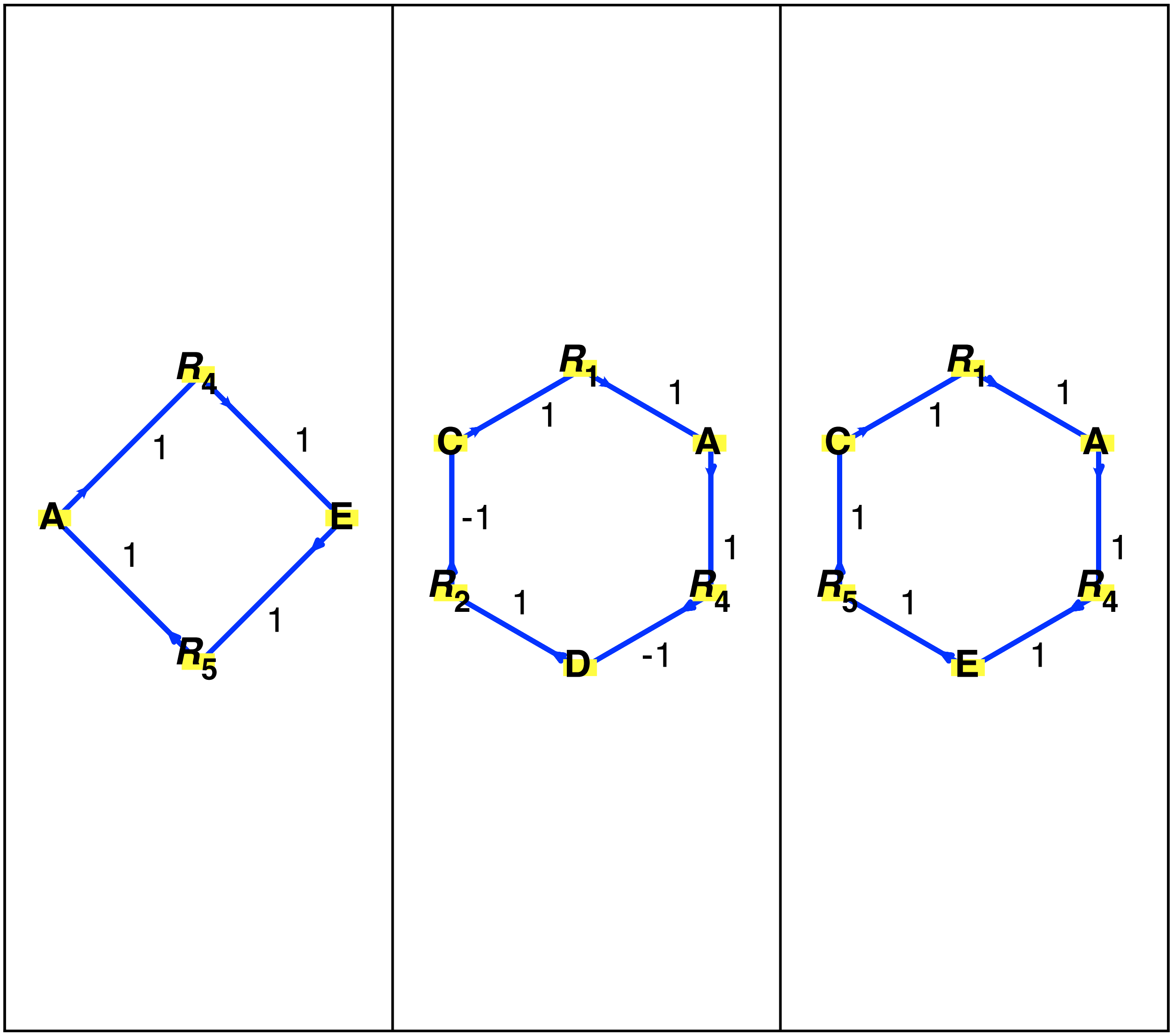
R_1
B
A
R_3
1
1
1
1
R_1
B
C
R_3
R_2
A
D
R_5
-1
1
1
1
1
-1
1
1
R_3
A
D
R_5
1
1
1
1

R_1 A B R_2 R_3 D	R_1 A B R_2 R_4 C	R_4 A E R_5

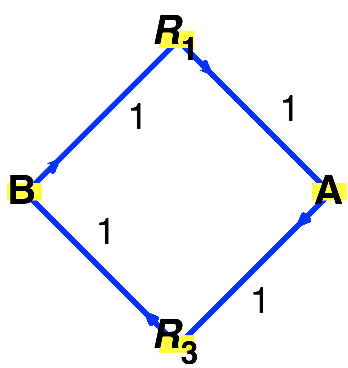
		

No. 40: injectiveEx3_2969.csv

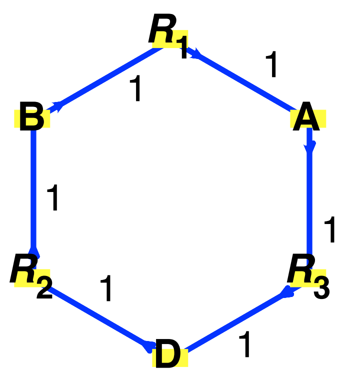
 R_1 1 1 B A 1 1 R_3	 R_1 1 1 B A 1 1 R_2 1 R_3 D 1	 R_1 1 B 1 A 1 1 R_2 1 R_4 1 C 1 E R_5 1



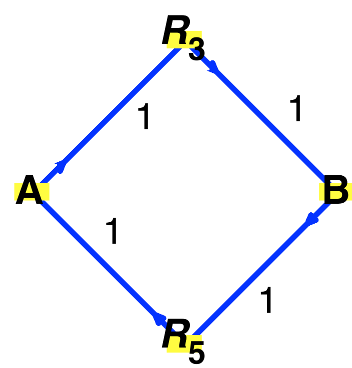
No. 41: injectiveEx3_2970.csv



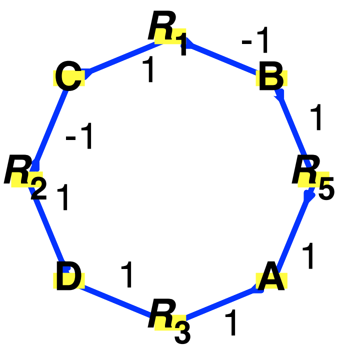
R_1
B
A
R_3
1
1
1
1

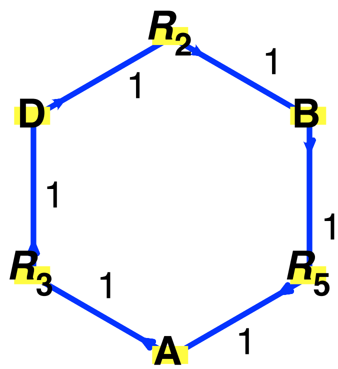


R_1
B
A
R_2
R_3
D
1
1
1
1
1
1

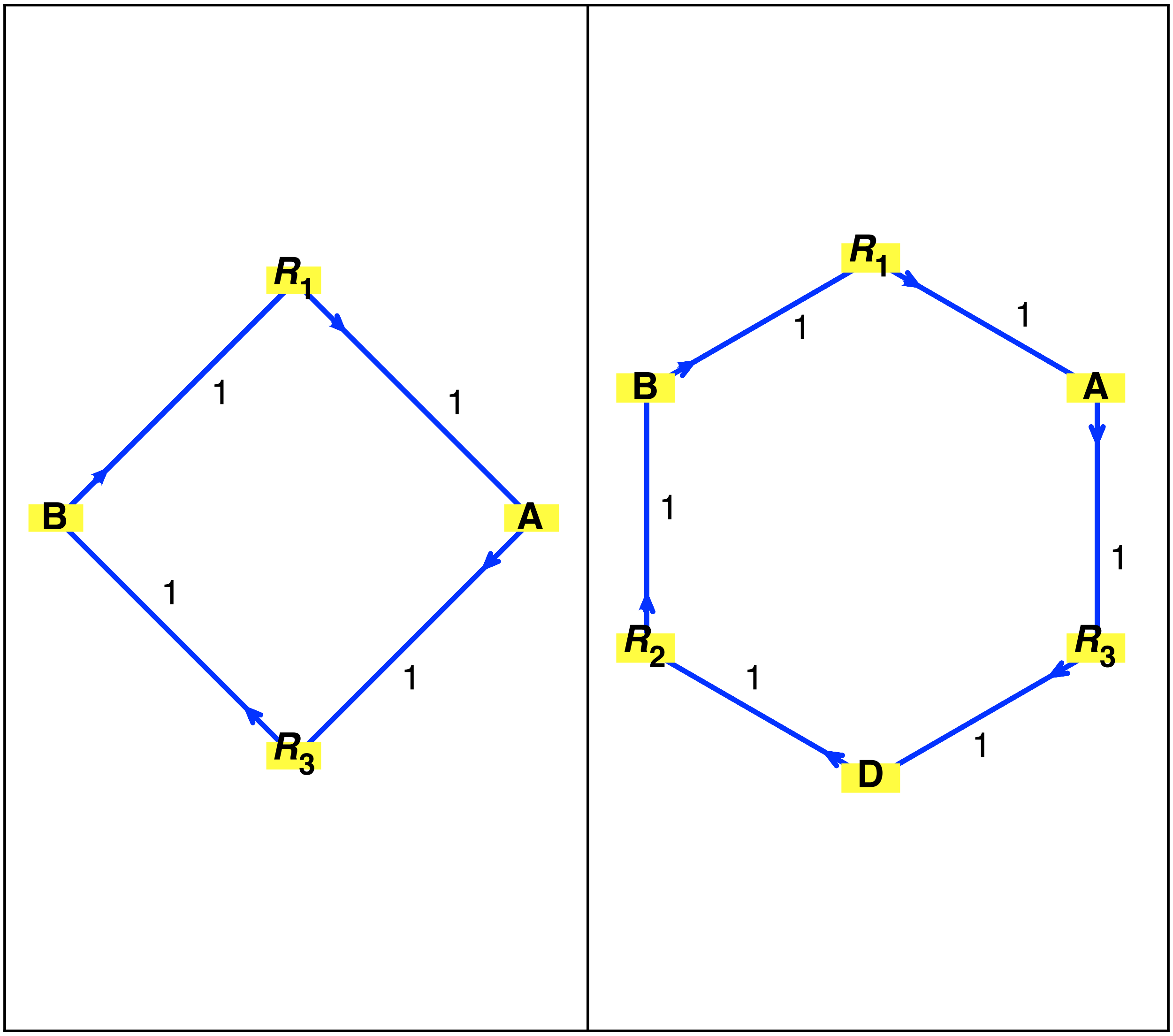


R_3
A
B
R_5
1
1
1
1

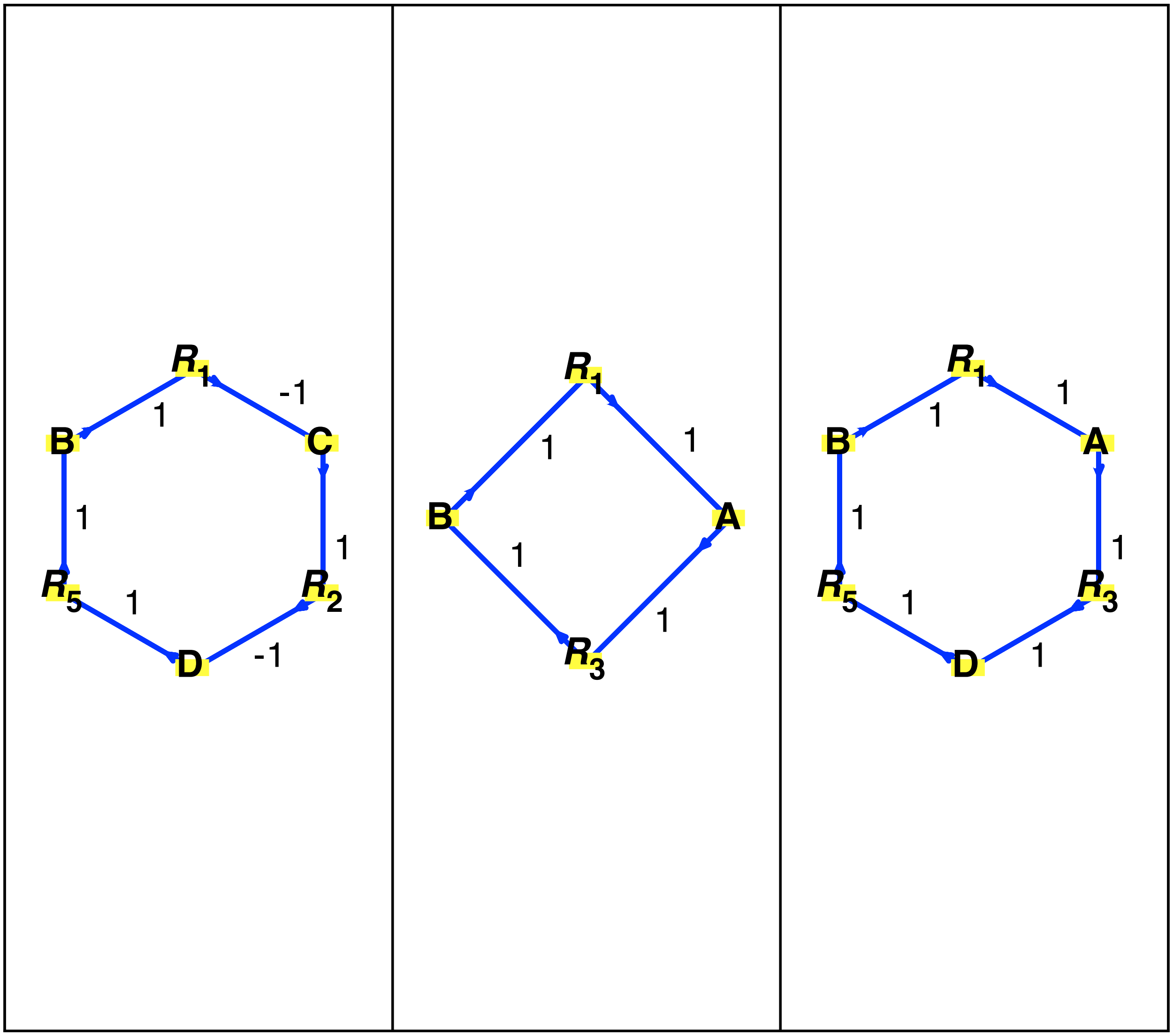




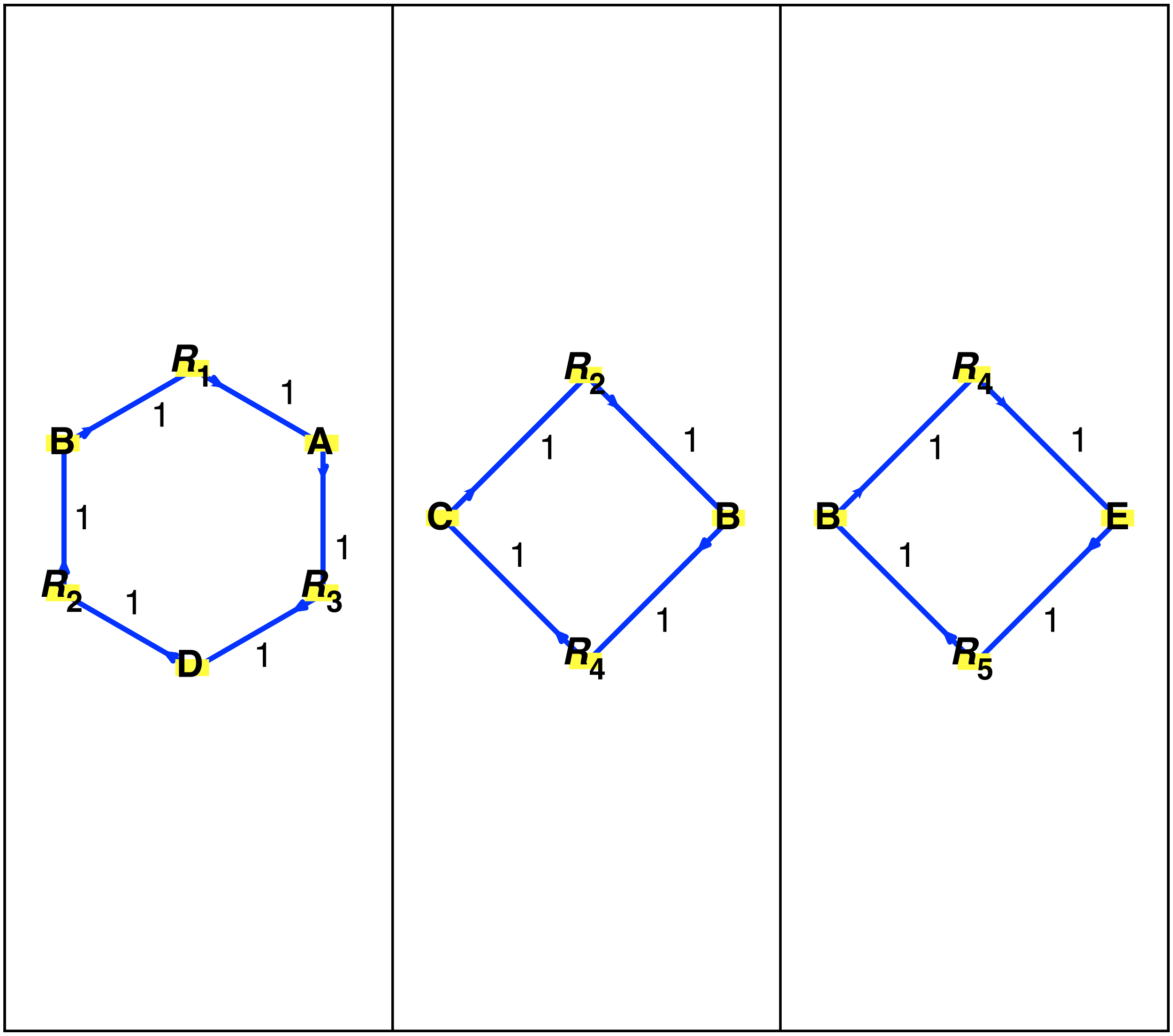
No. 42: injectiveEx3_2971.csv



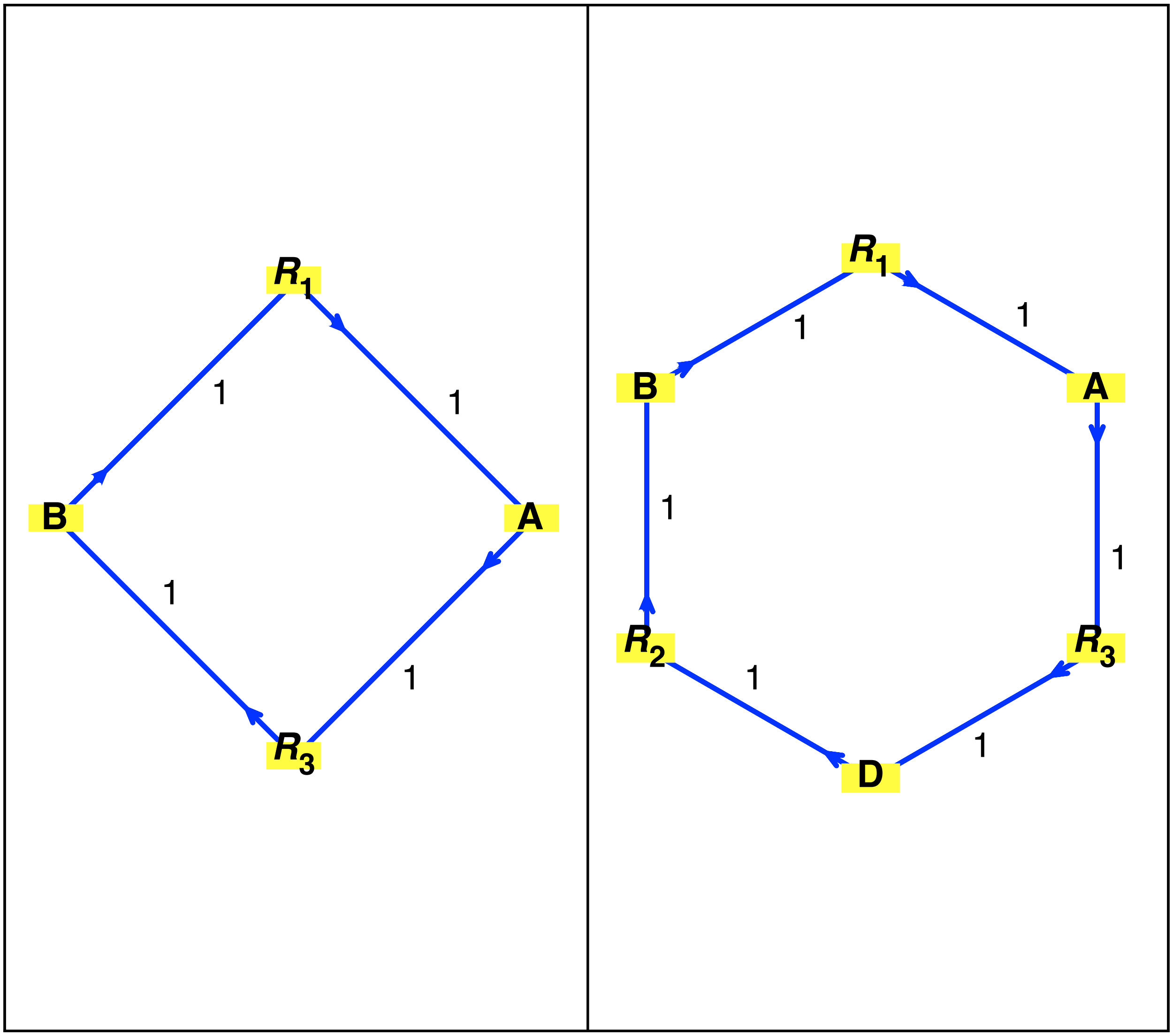
No. 43: injectiveEx3_2972.csv



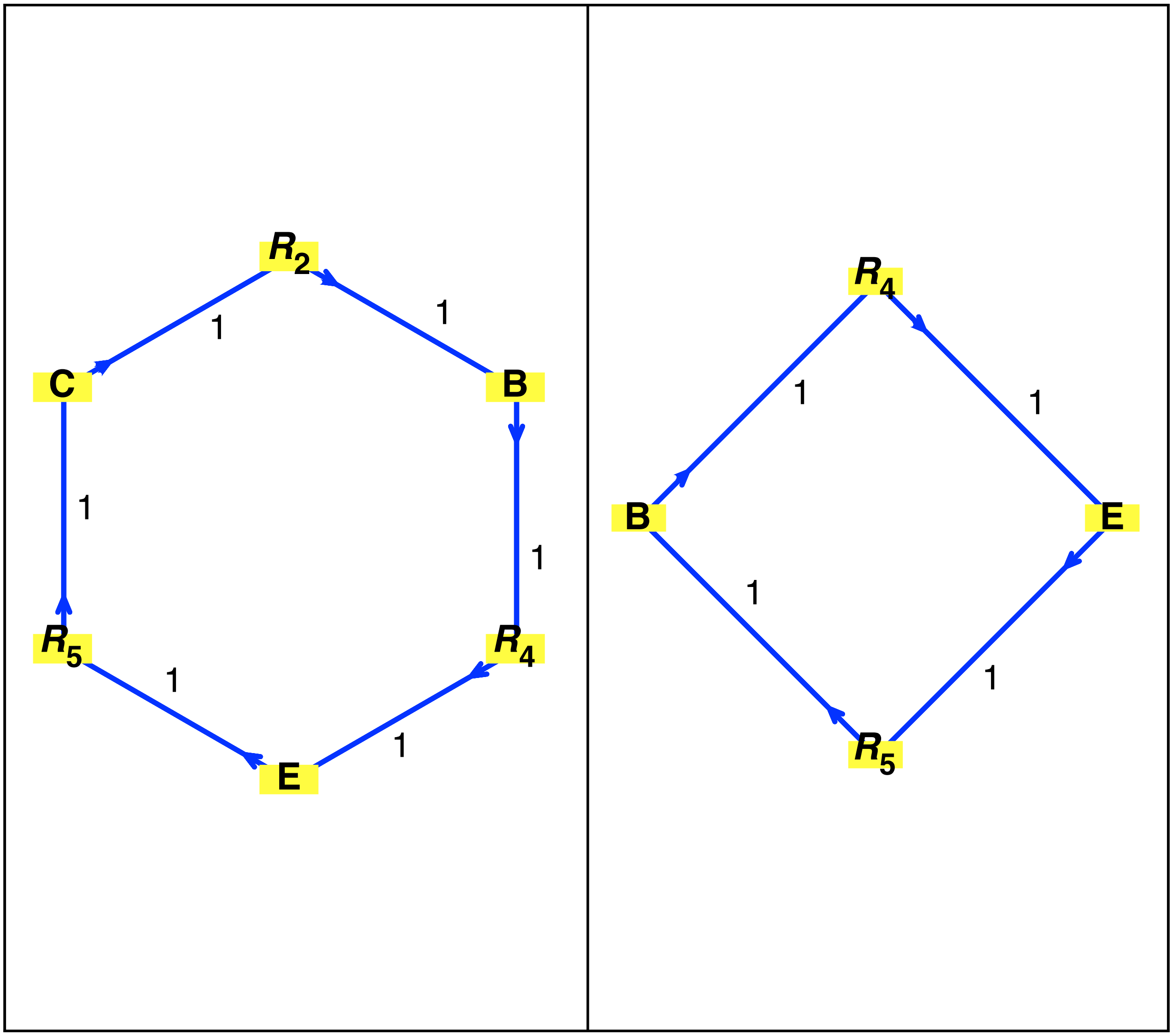
R1
B
C
R5
R2
D
1
-1
1
1
1
1
-1
R1
B
A
R3
1
1
1
1
R1
B
A
R5
R3
D
1
1
1
1
1
1



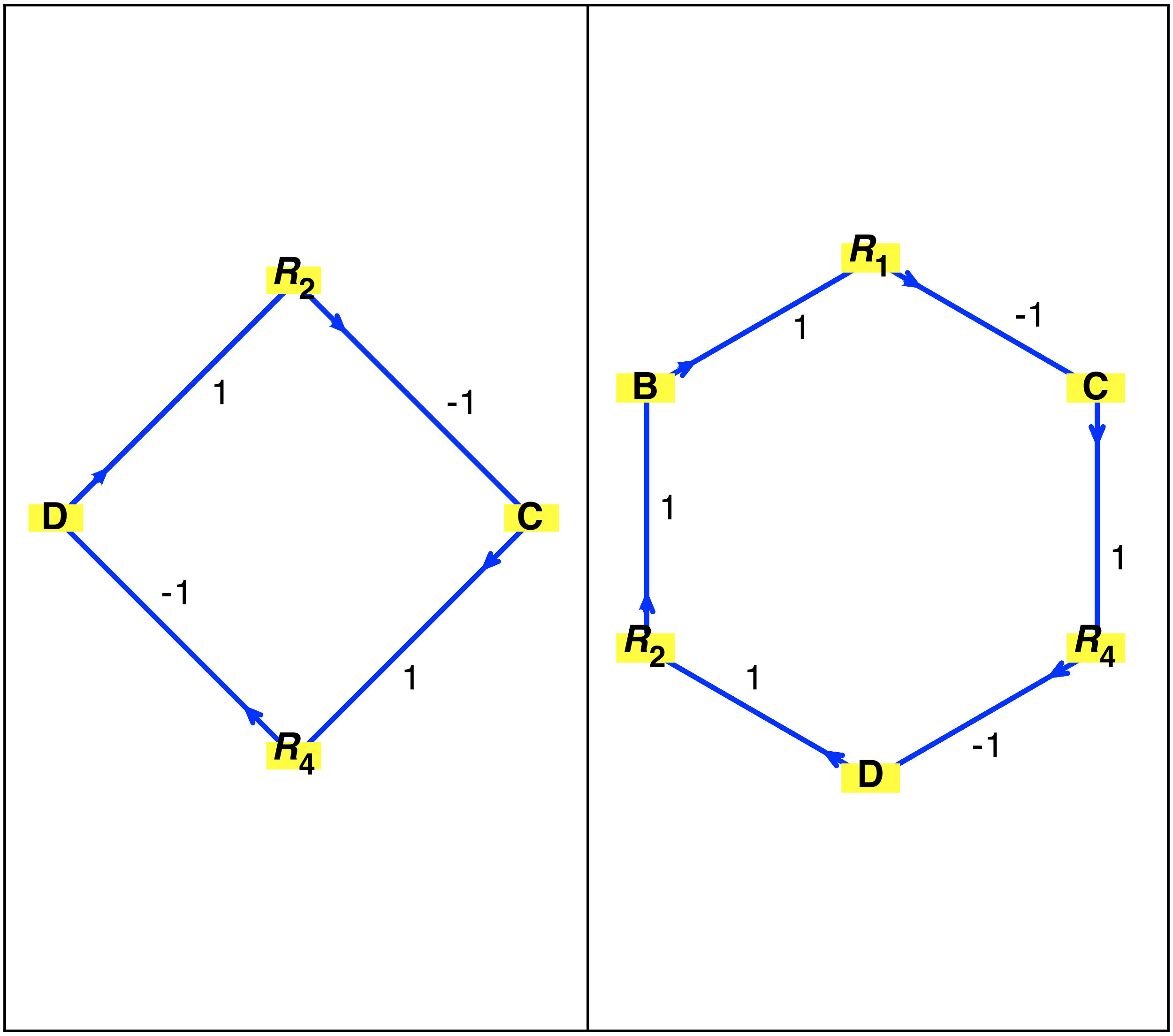
No. 44: injectiveEx3_2974.csv



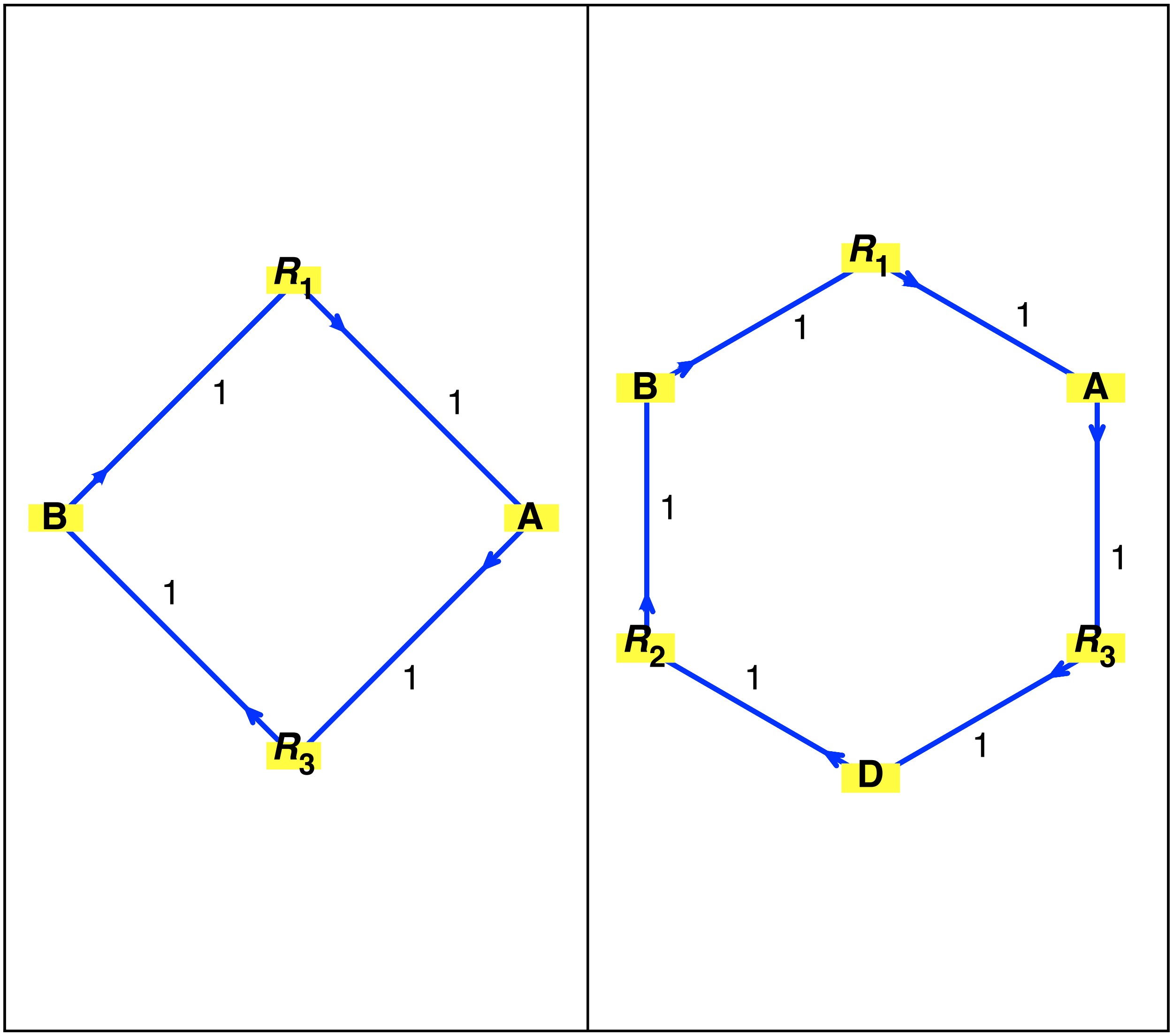
R_1
B
A
R_3
1
1
1
1
R_1
B
A
R_2
R_3
D
1
1
1
1
1
1



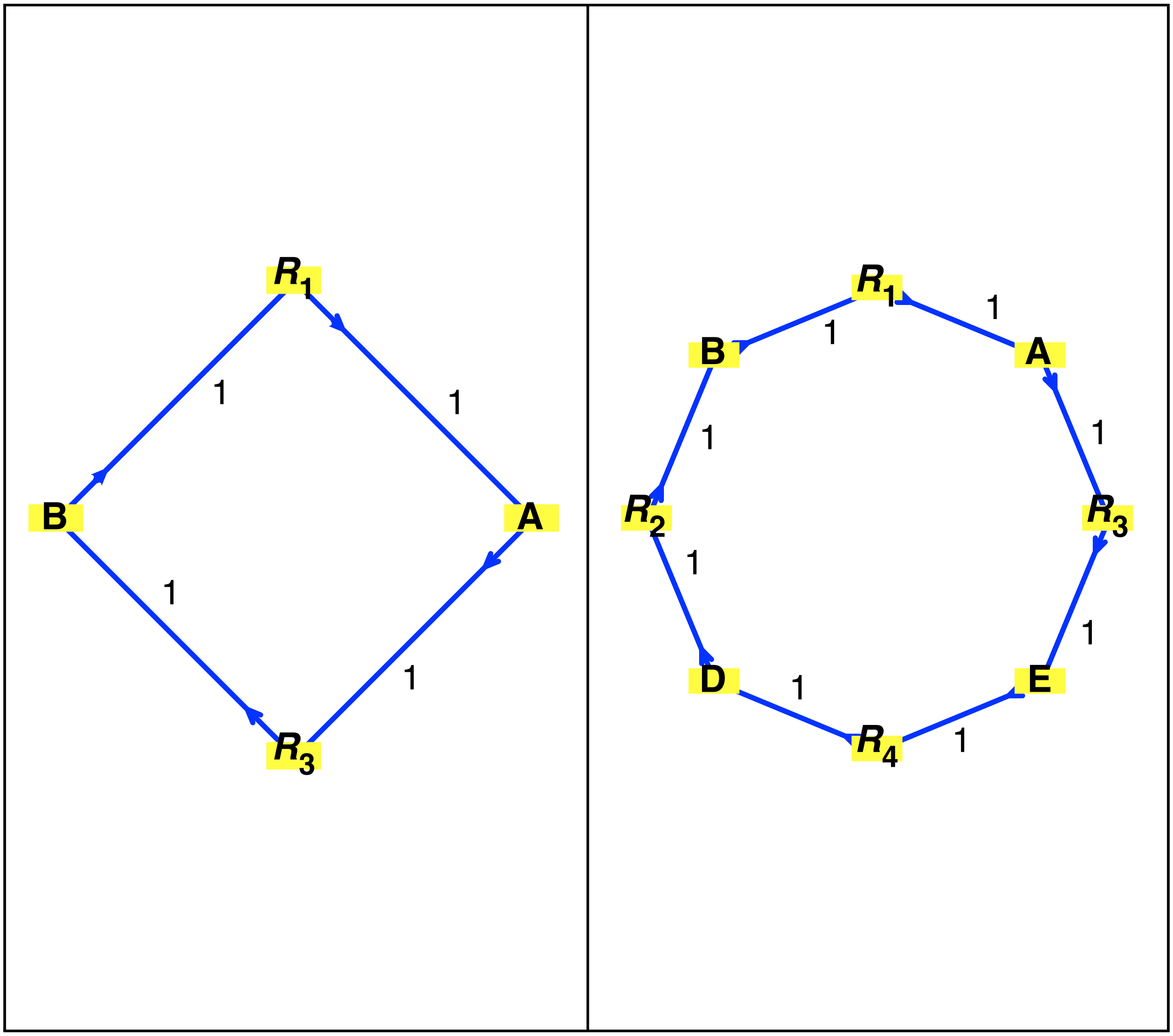
No. 45: injectiveEx3_2975.csv



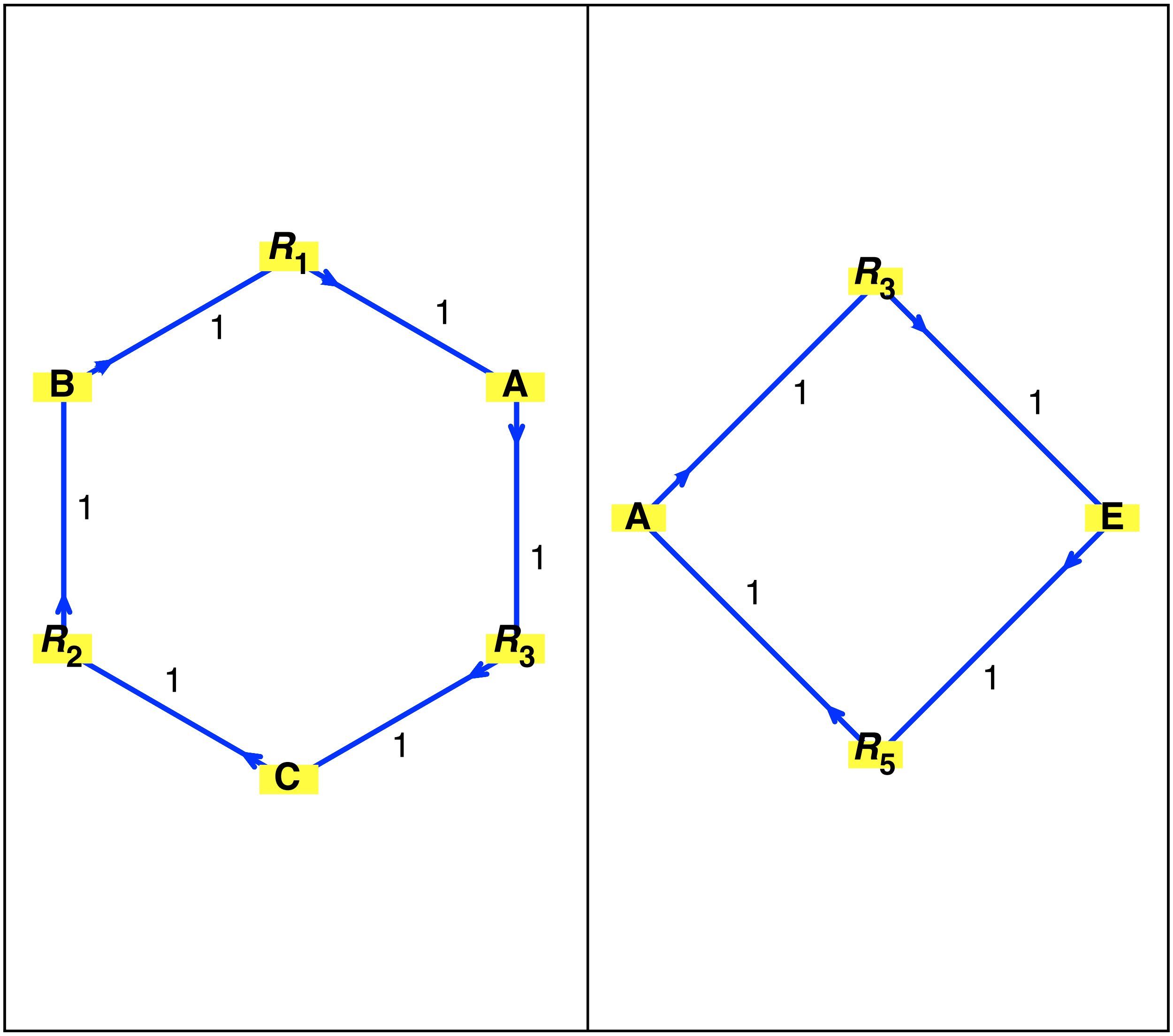
R2
D
C
R4
1
-1
-1
1
R1
B
C
R2
R4
D
1
-1
1
1
1
-1



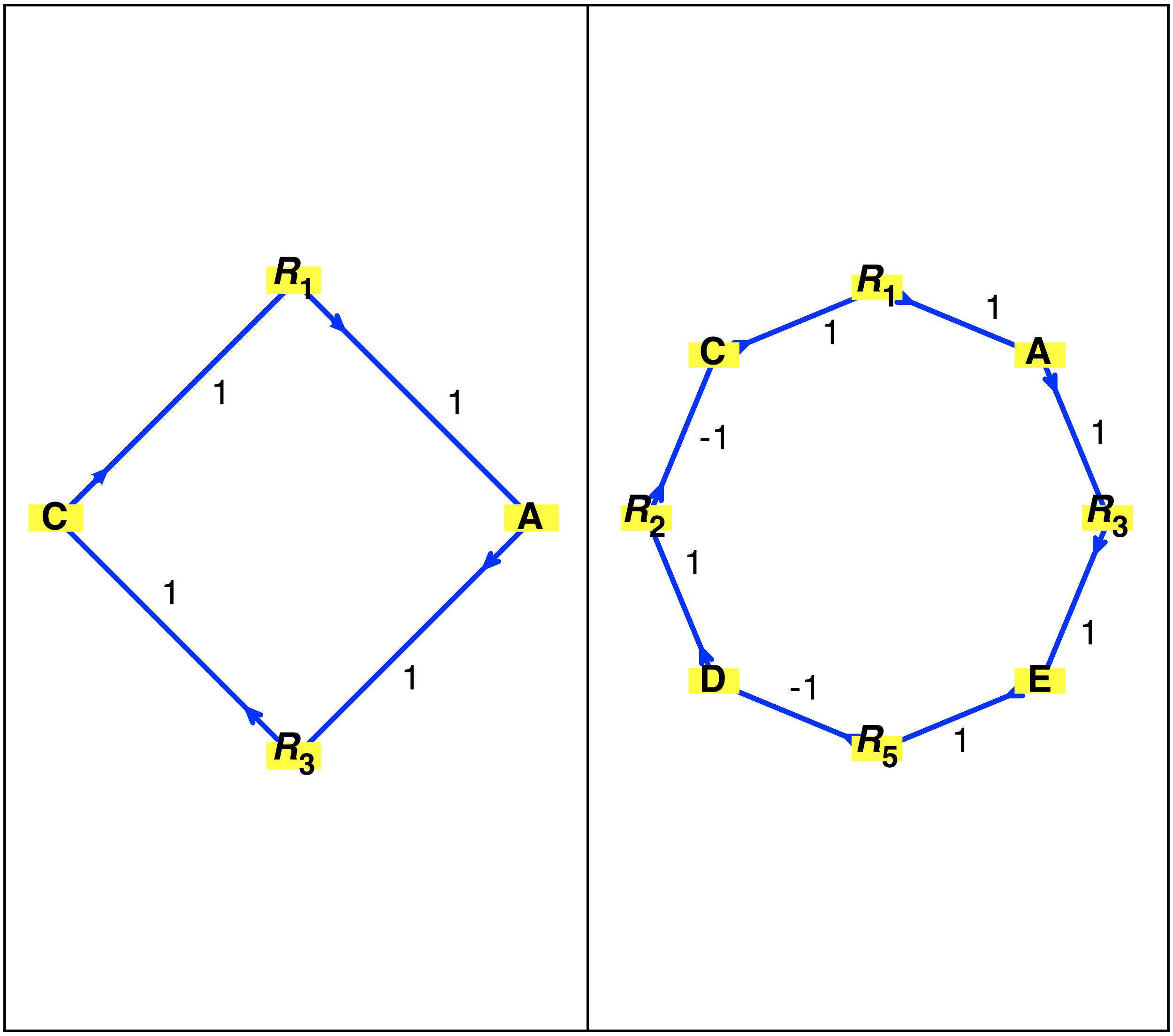
No. 46: injectiveEx3_2980.csv



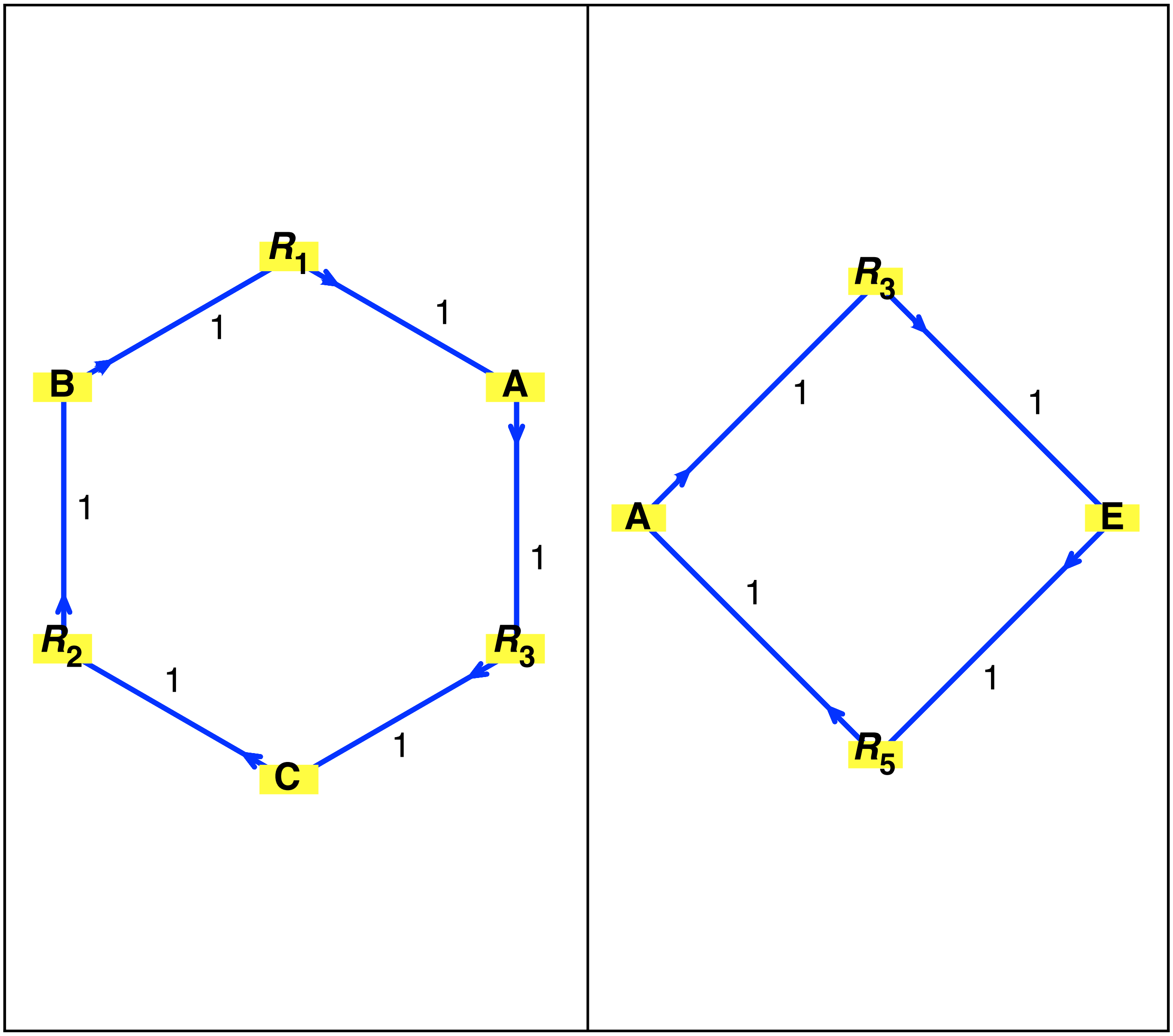
No. 47: injectiveEx3_2983.csv



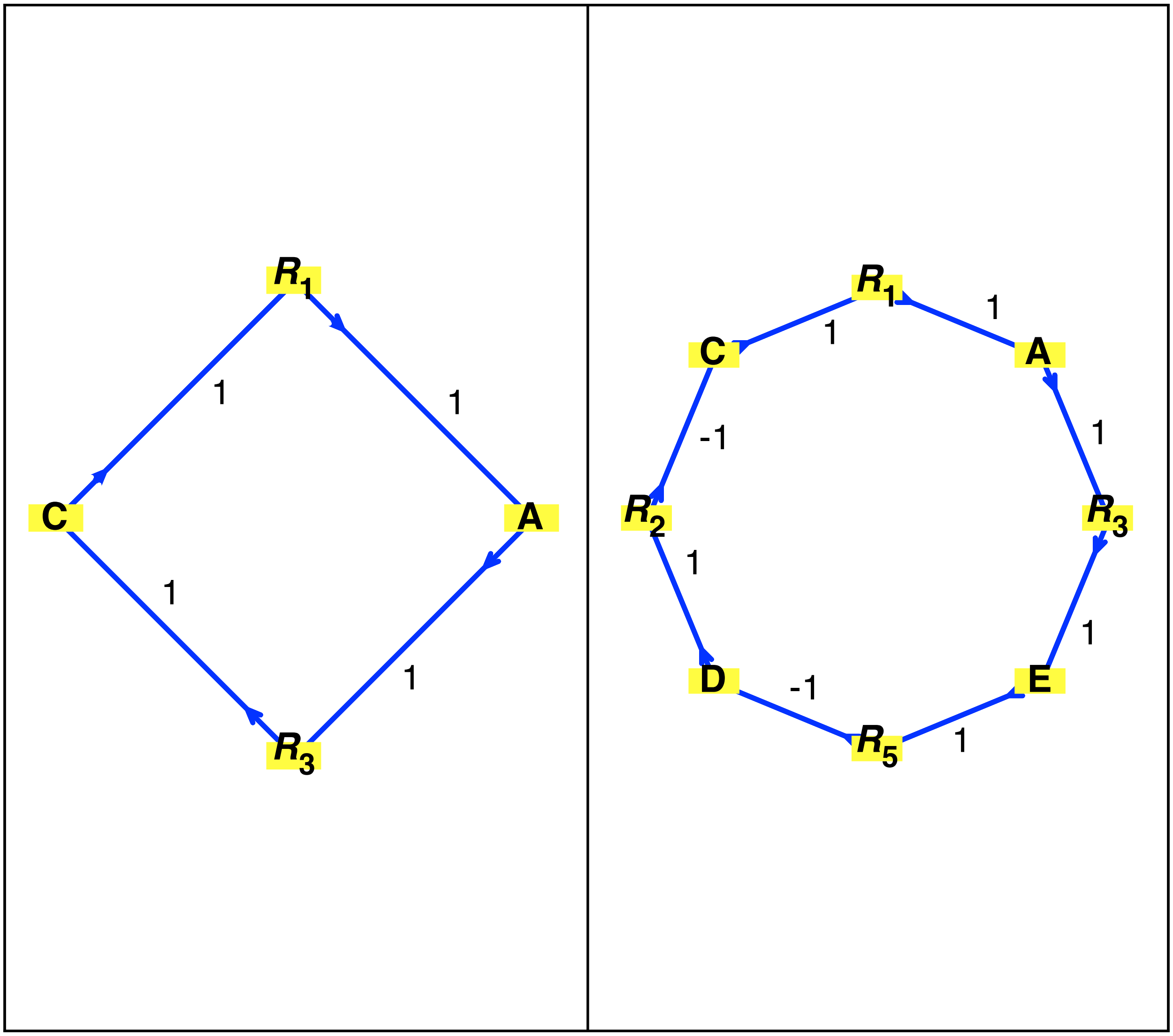
R_1
B
A
R_2
R_3
C
1
1
1
1
1
1
R_3
A
E
R_5
1
1
1
1



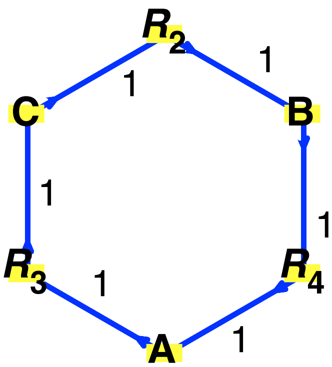
No. 48: injectiveEx3_2986.csv

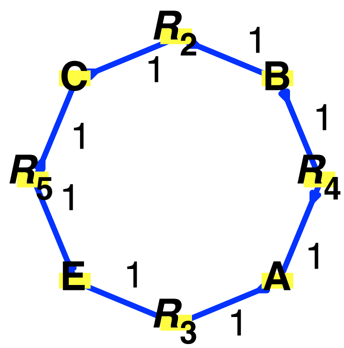


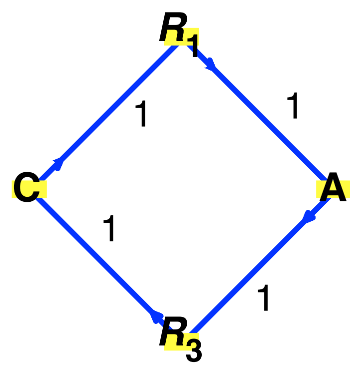
R1
B
A
R2
R3
C
1
1
1
1
1
1
R3
A
E
R5
1
1
1
1

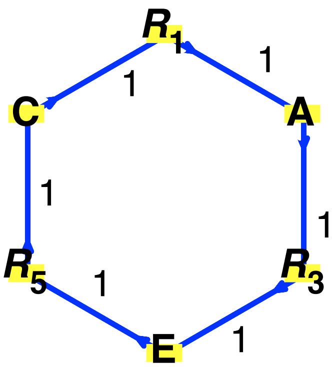


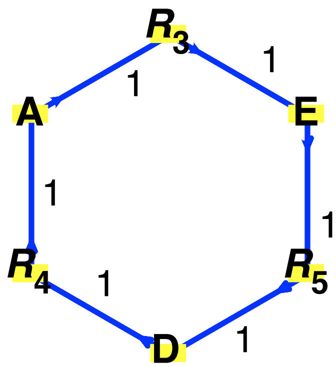
No. 49: injectiveEx3_2990.csv


R2
B
R4
A
R3
C
1
1
1
1
1
1

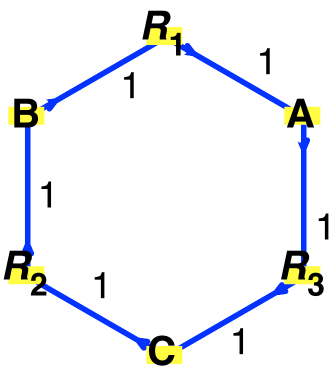
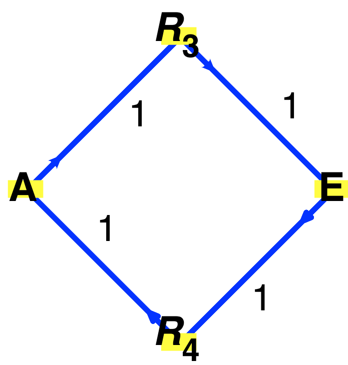
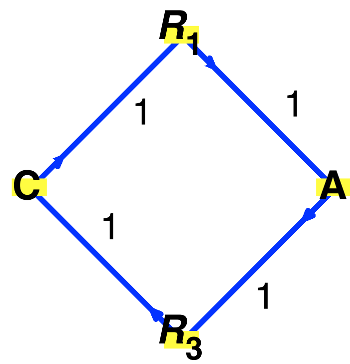

R2
B
R4
A
R3
E
R5
C
1
1
1
1
1
1
1
1

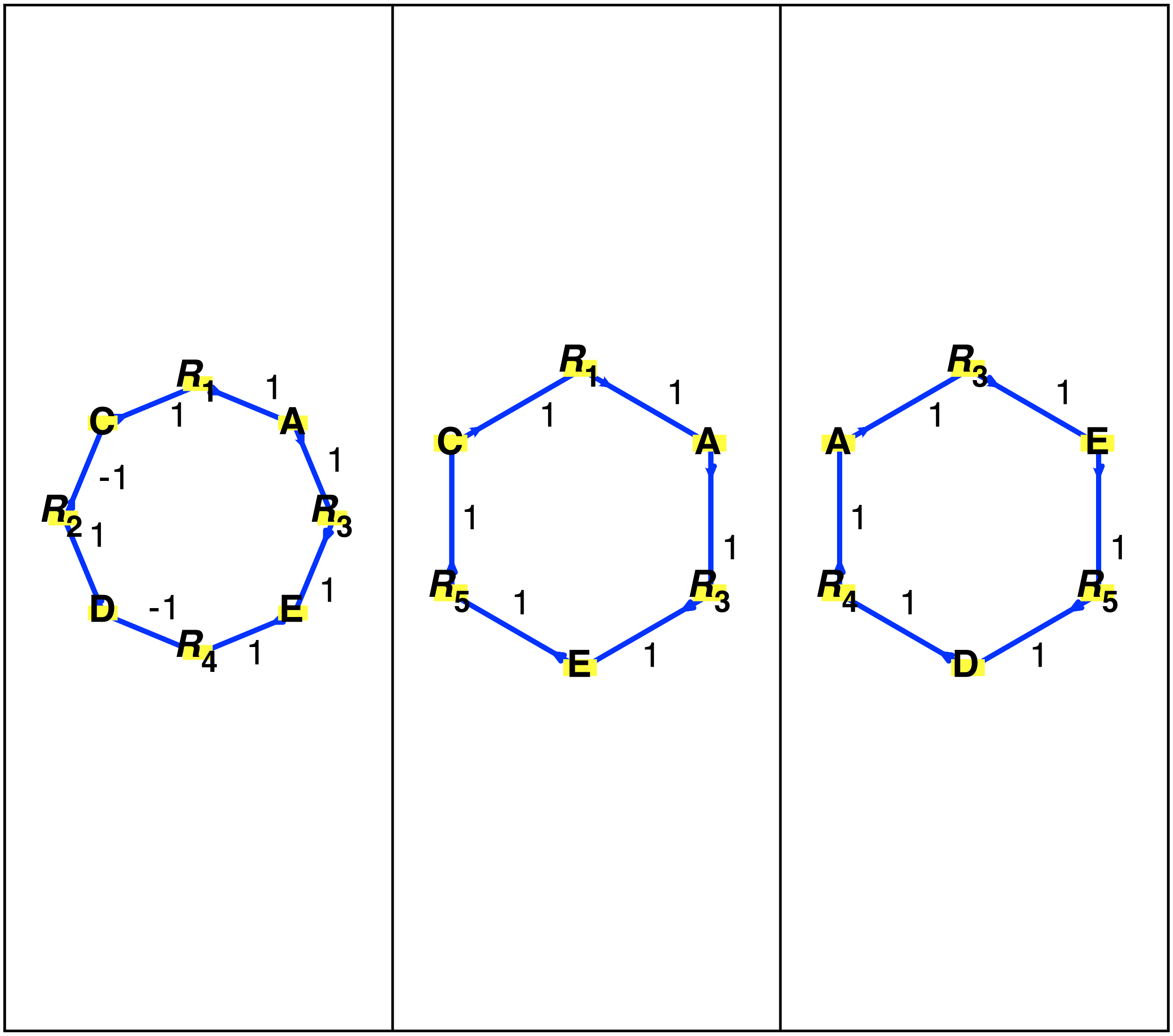

R1
A
R3
C
1
1
1
1



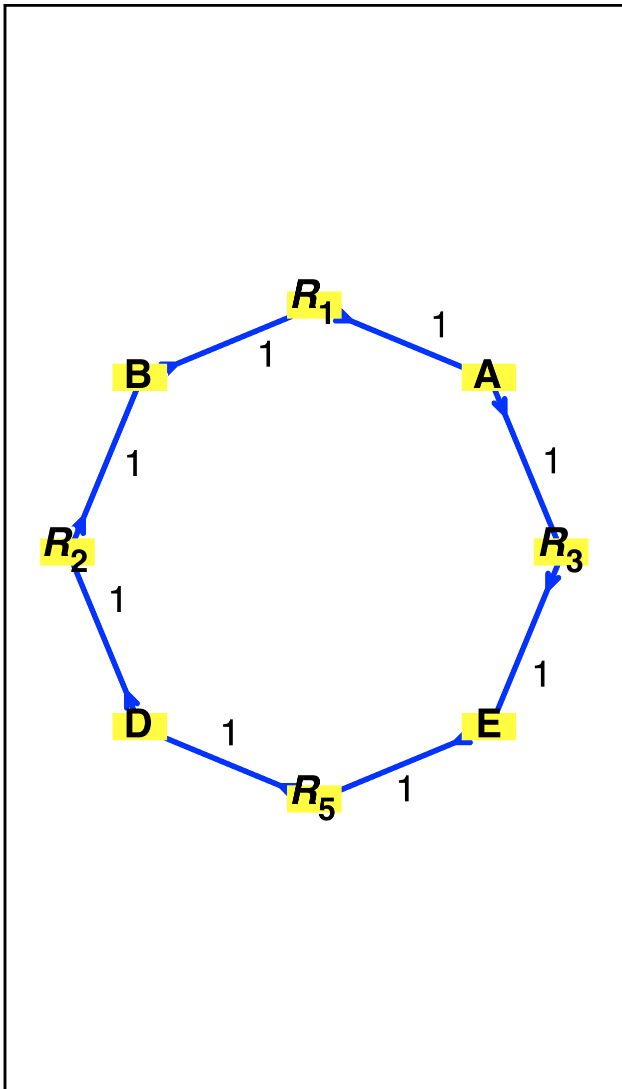


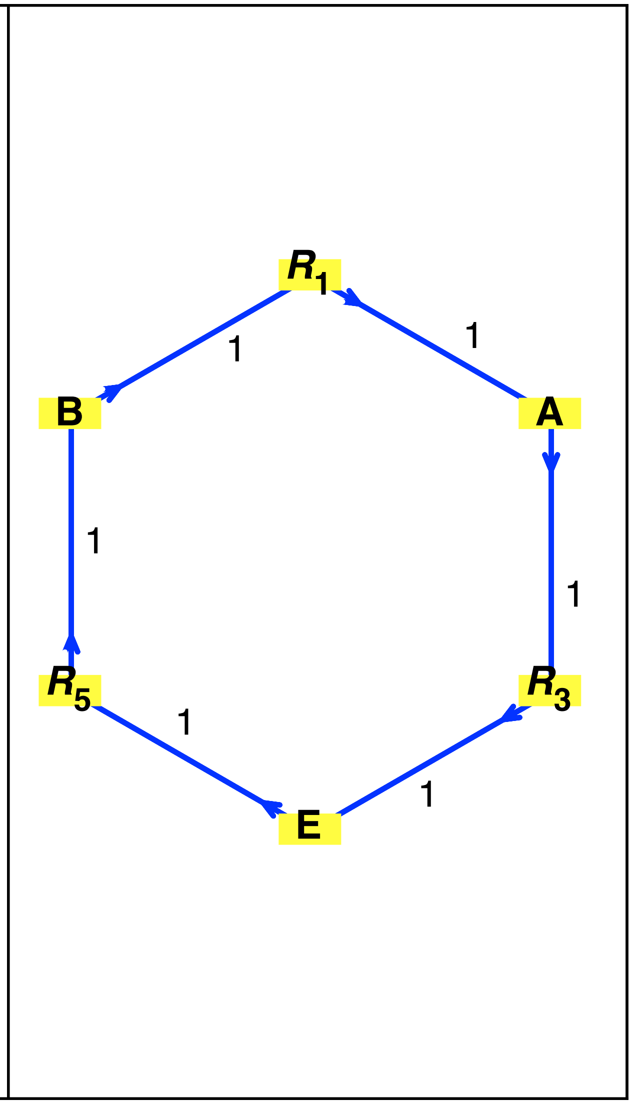
No. 50: injectiveEx3_2992.csv

R_1 A B R_2 R_3 C 1 1 1 1 1 1	R_3 A E R_4 1 1 1 1	R_1 C A R_3 1 1 1 1

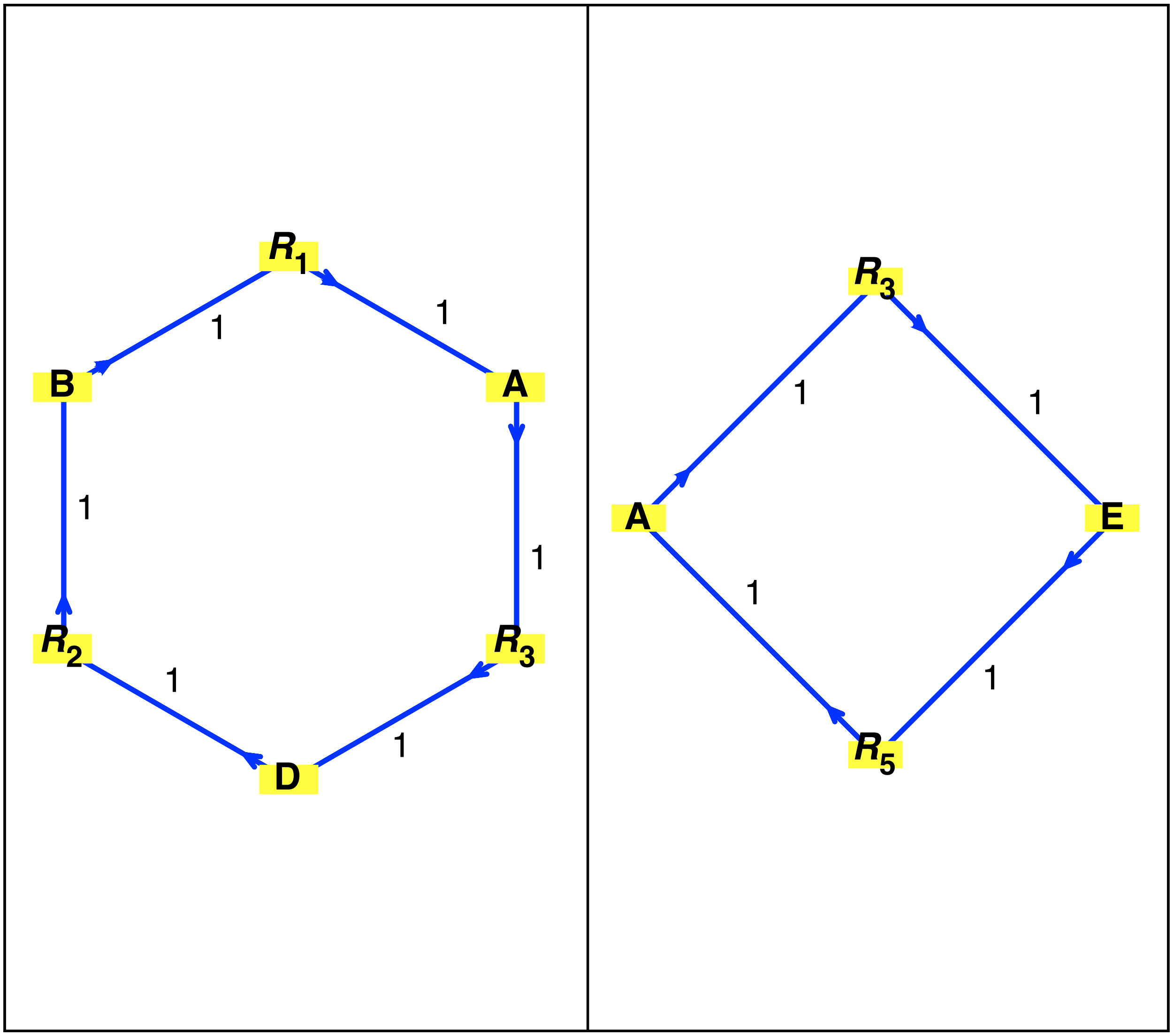


No. 51: injectiveEx3_2996.csv

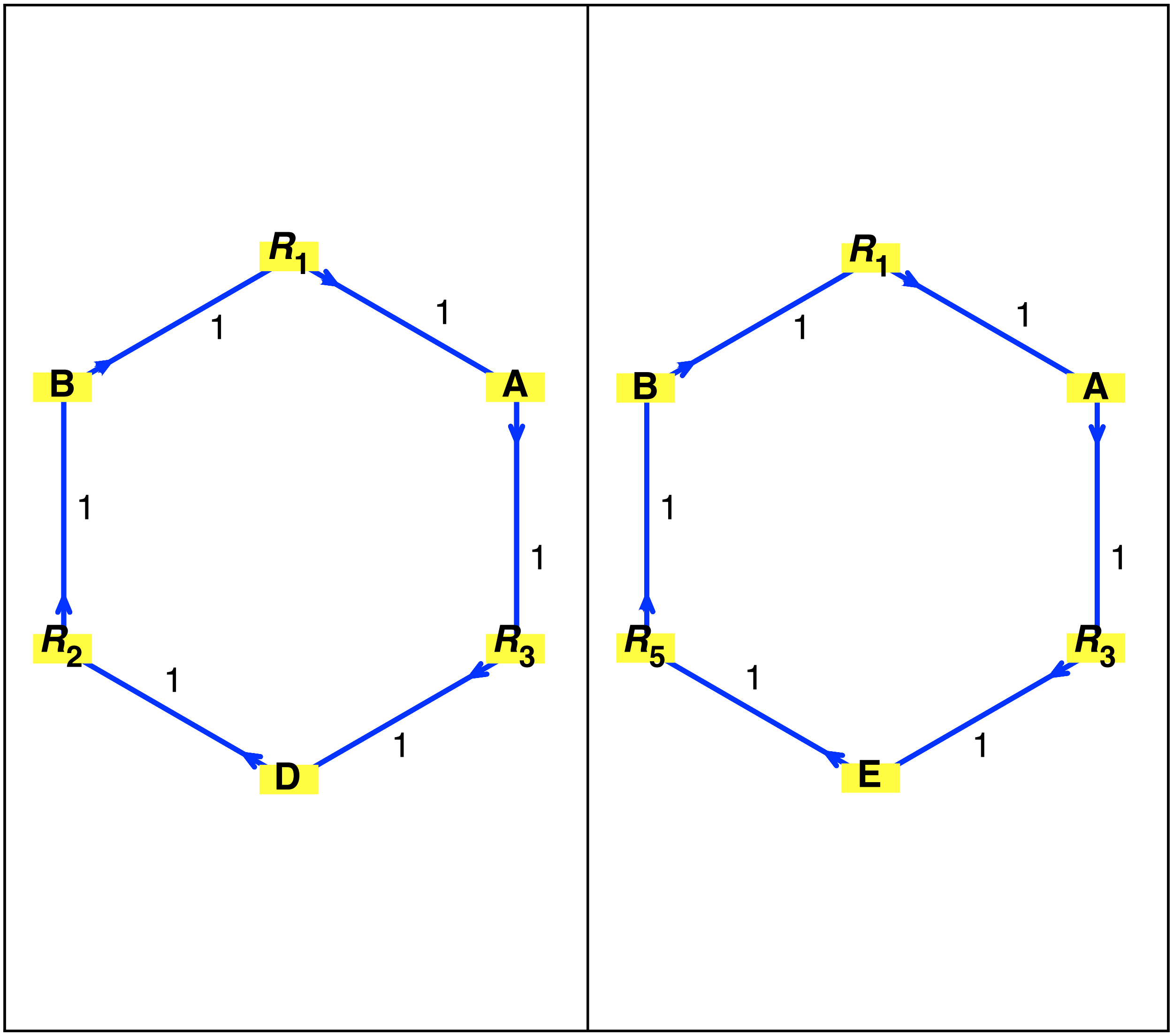




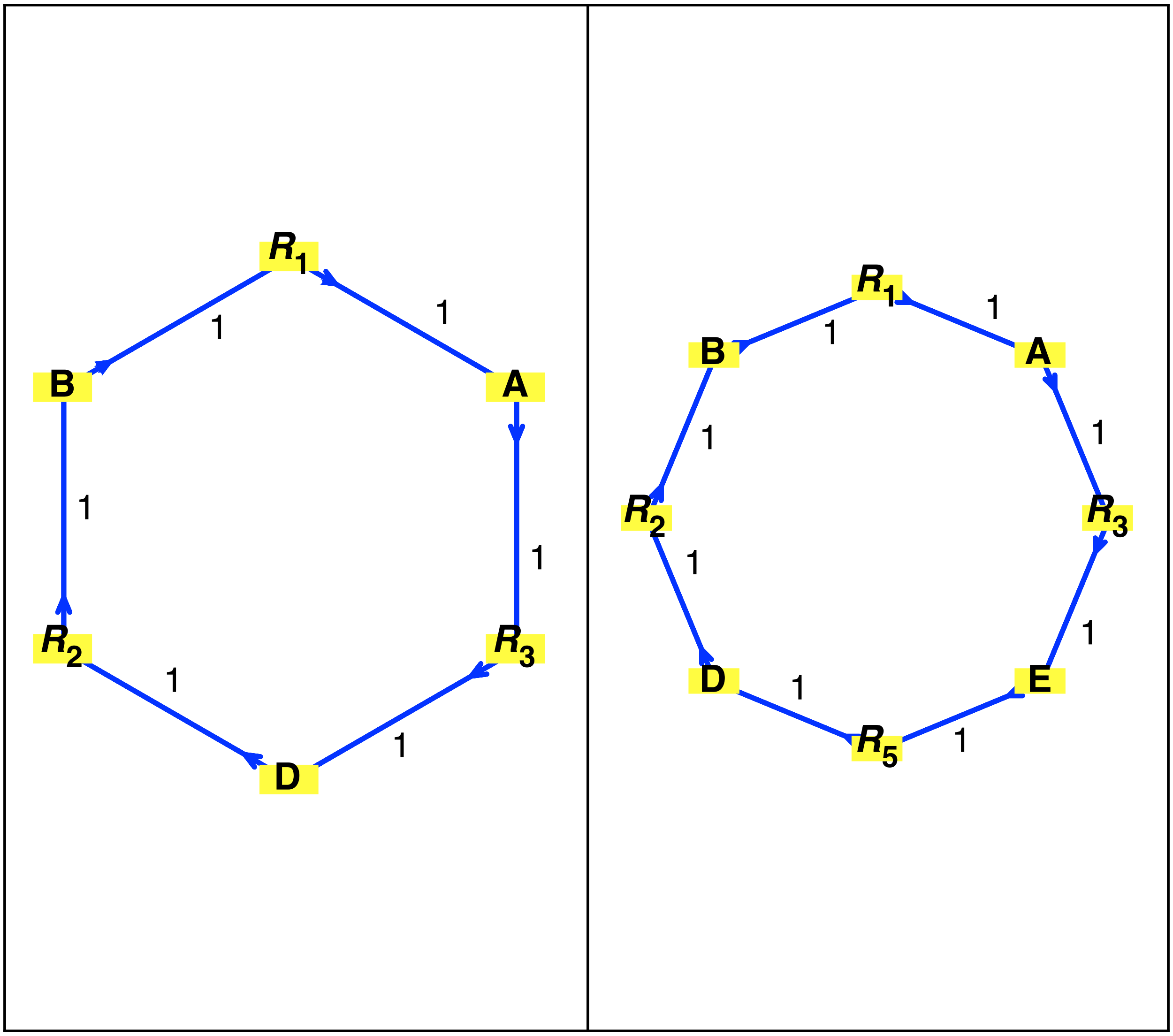
No. 52: injectiveEx3_3000.csv



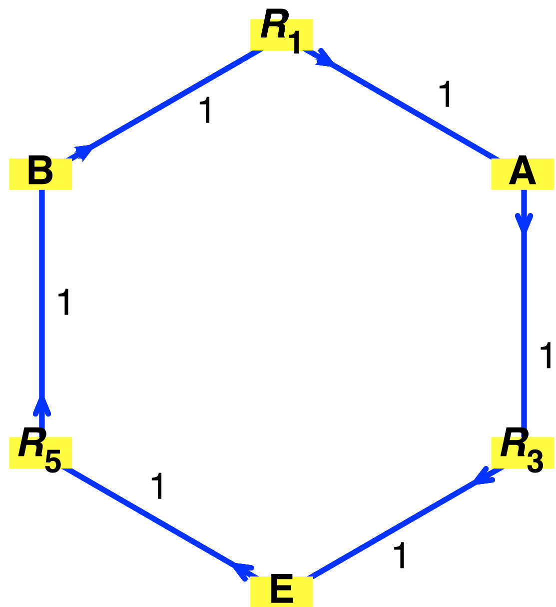
No. 53: injectiveEx3_3002.csv



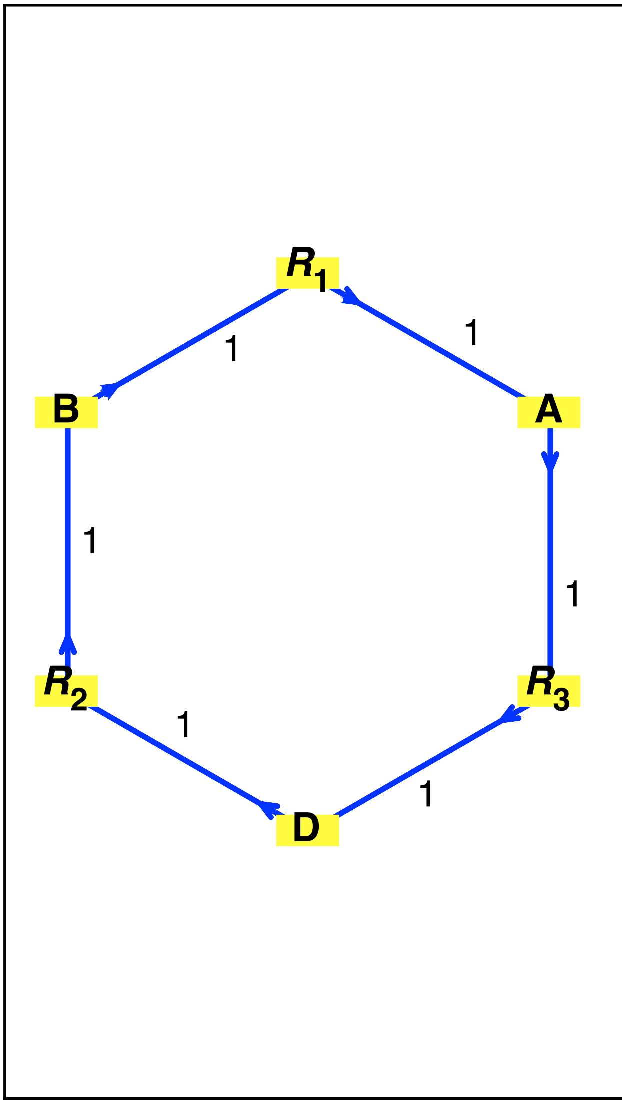
No. 54: injectiveEx3_3003.csv

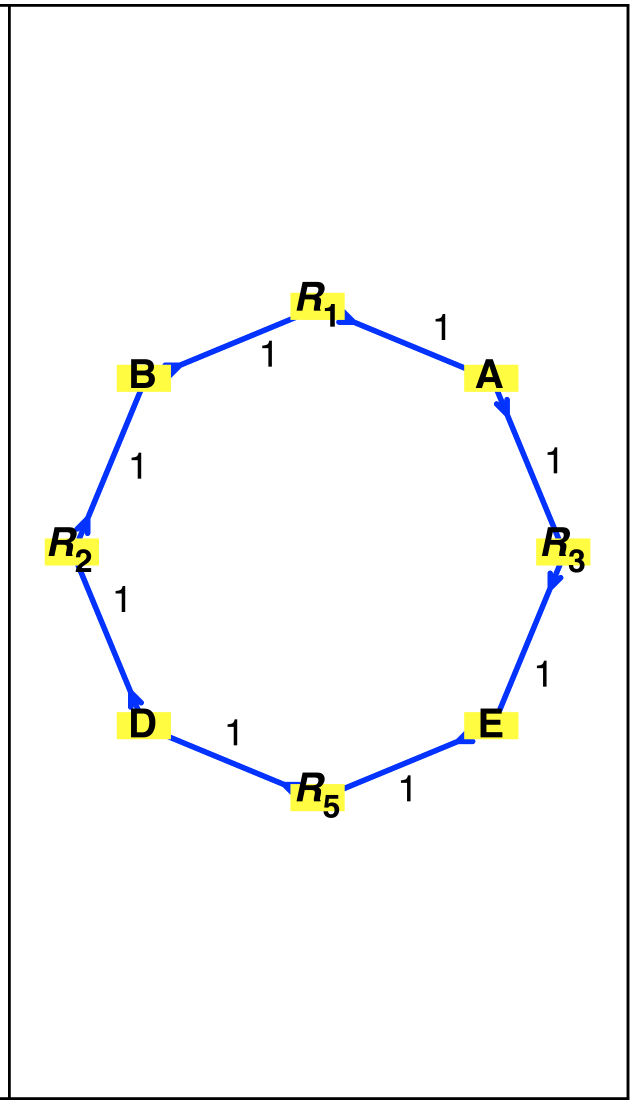


R_1
A
B
R_2
R_3
D
1
R_1
A
B
R_2
R_3
D
E
R_5
1

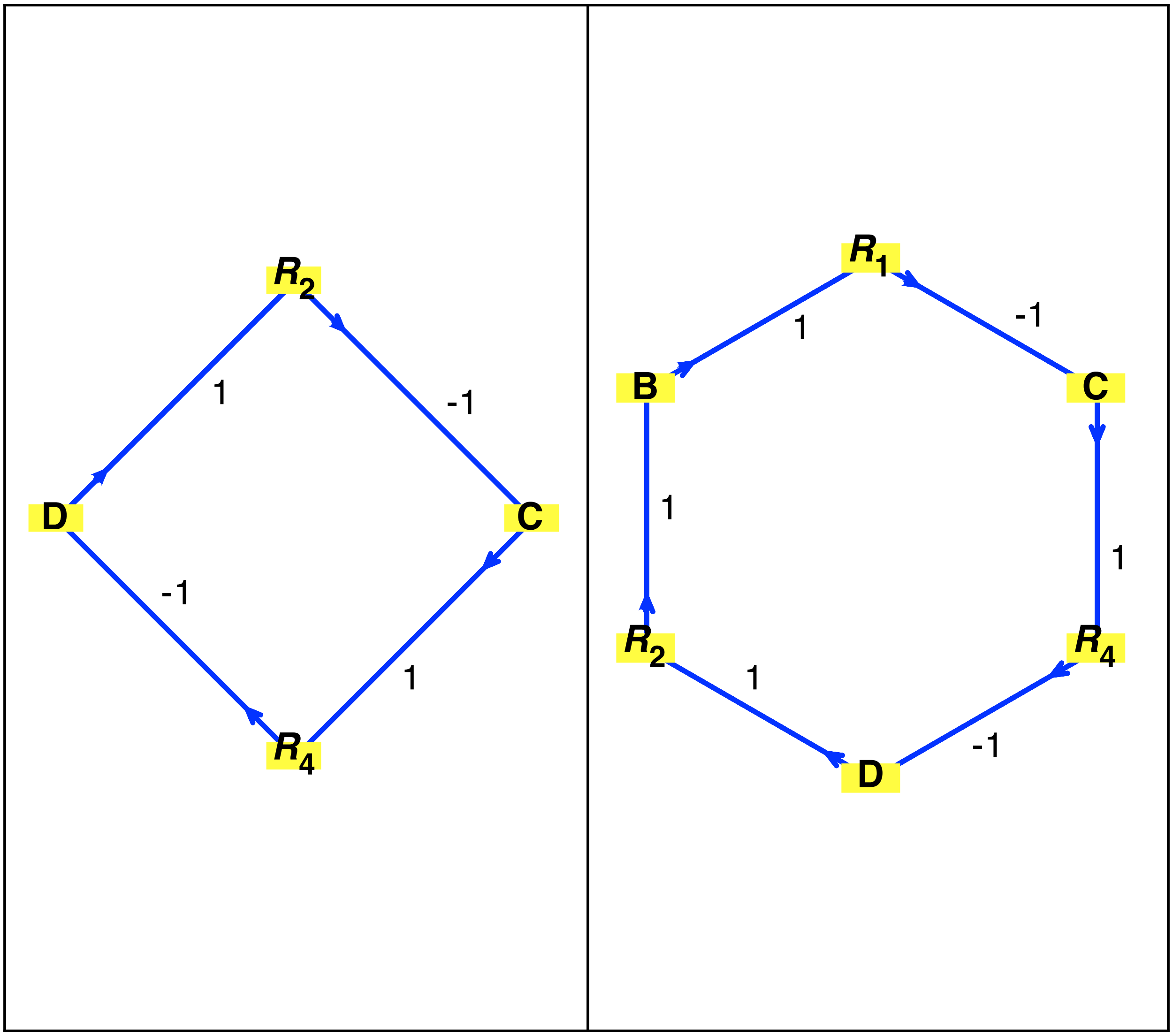


No. 55: injectiveEx3_3004.csv

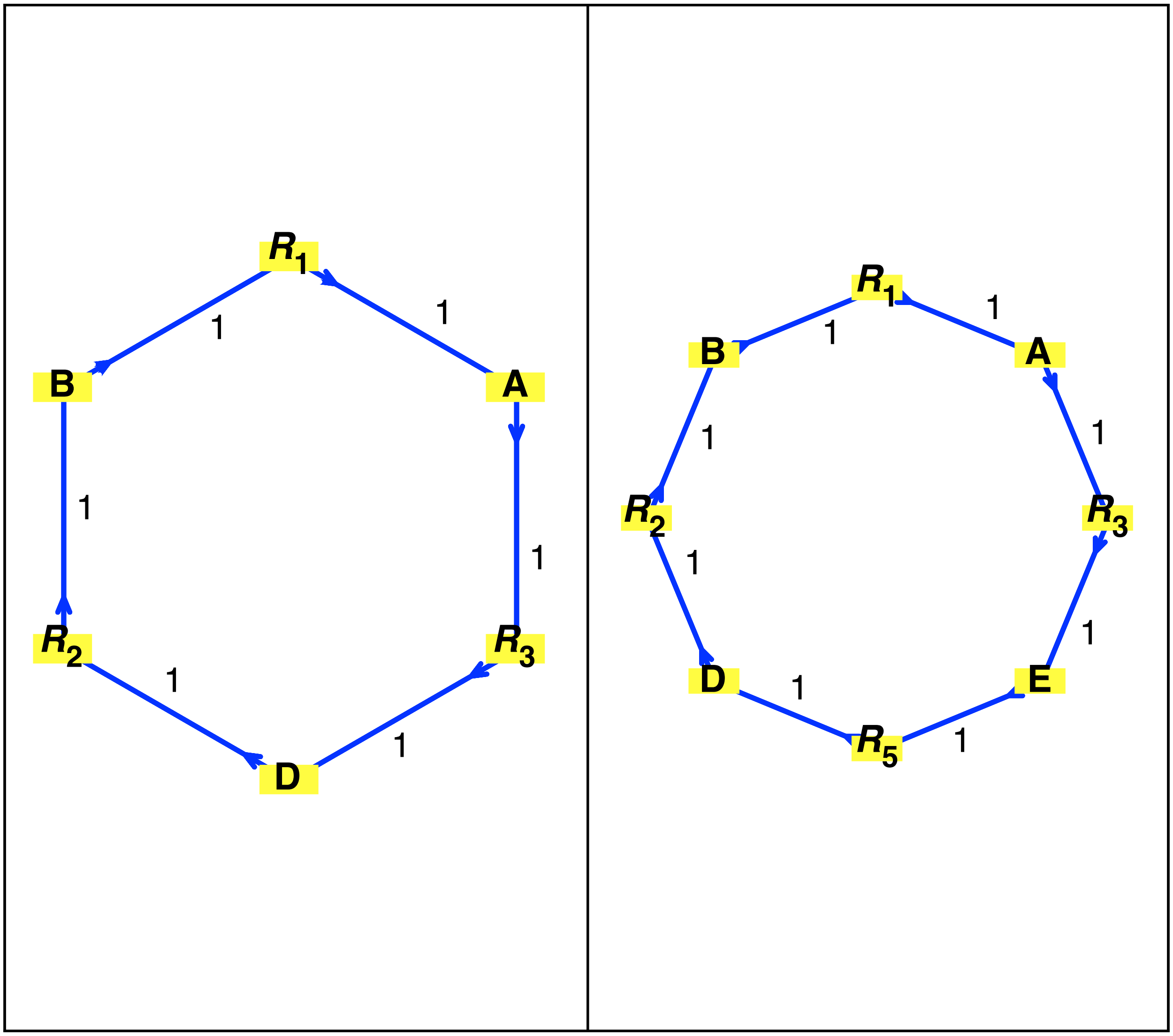




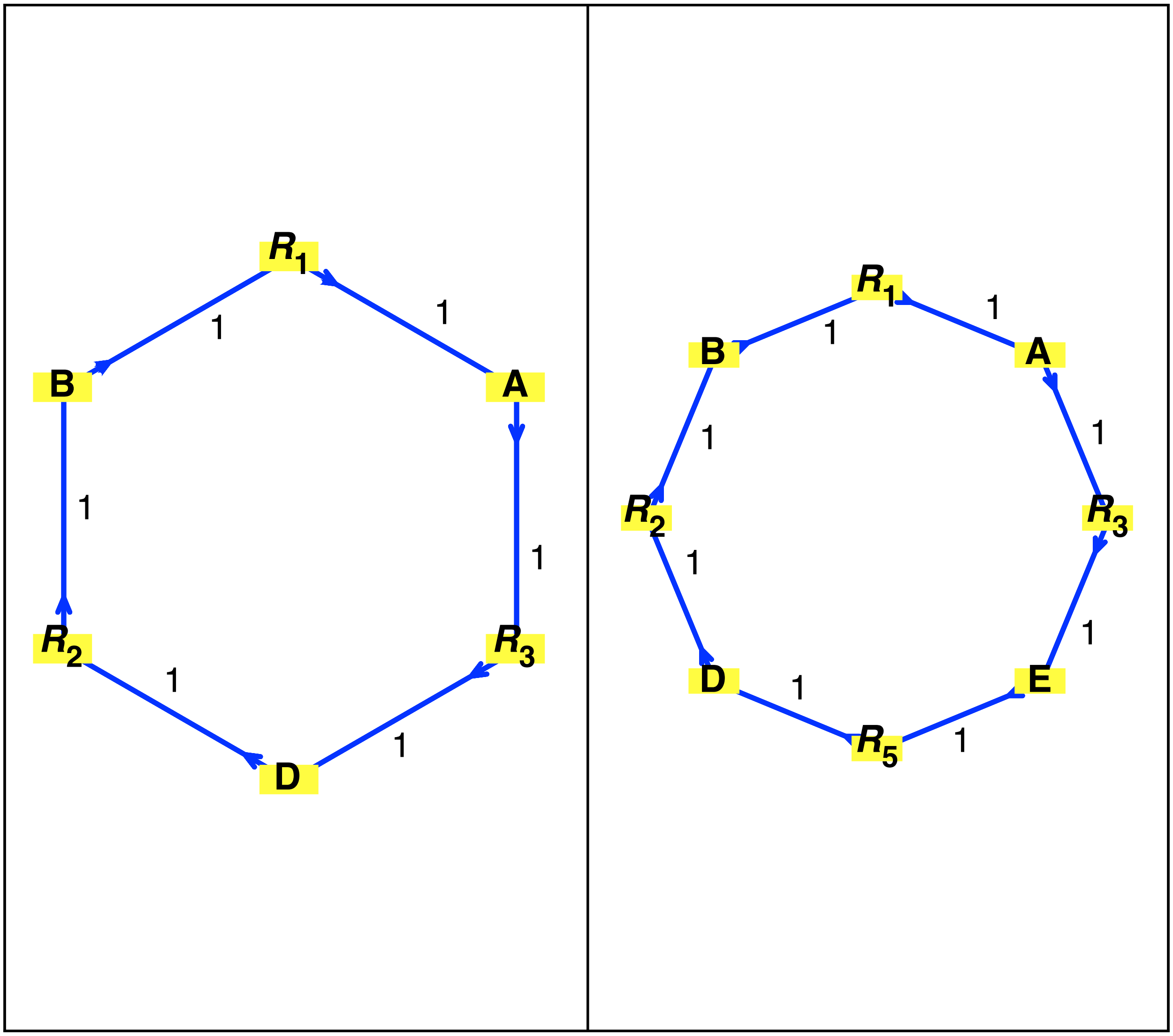
No. 56: injectiveEx3_3007.csv



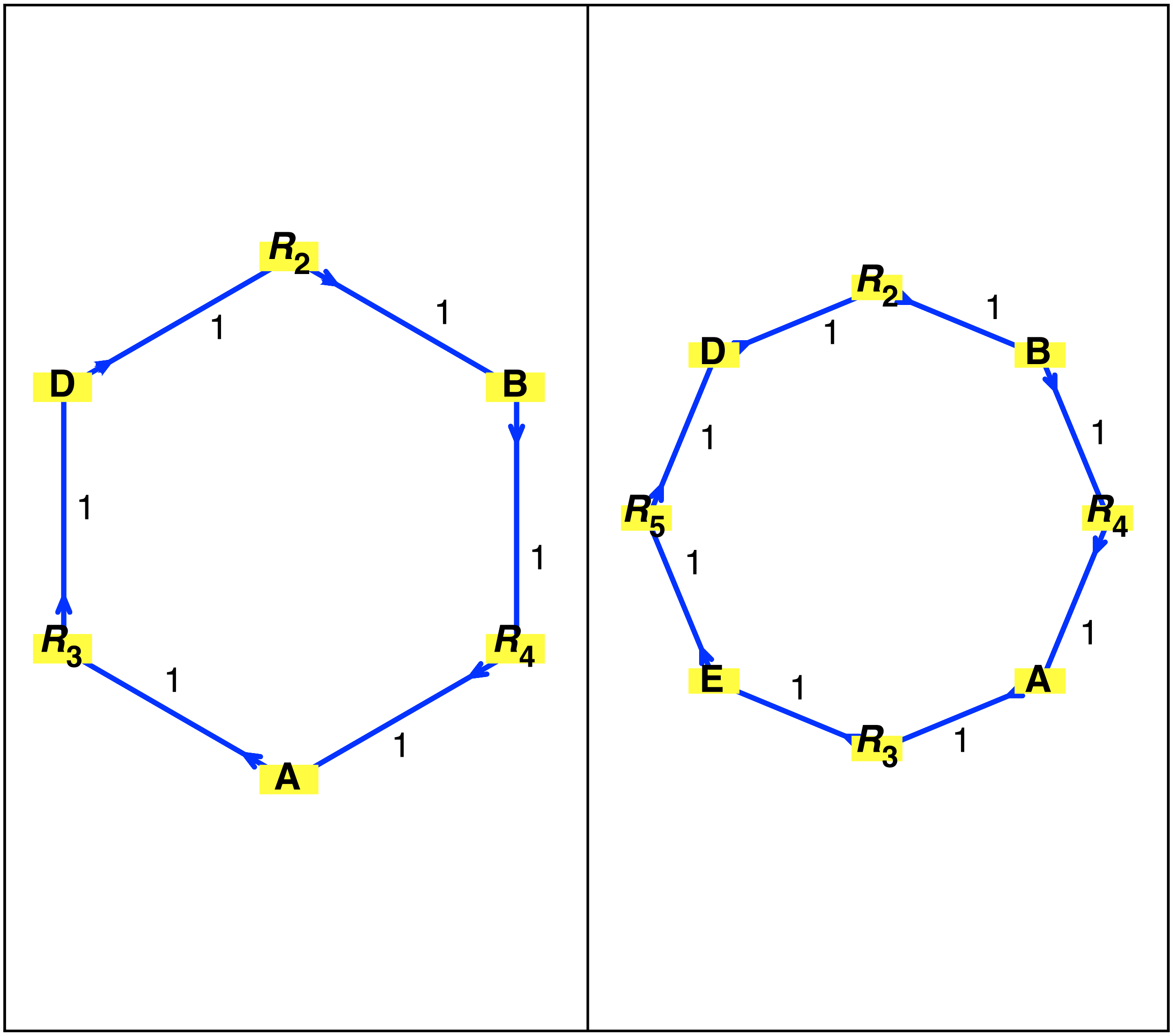
R_2
D
C
R_4
1
-1
-1
1
R_1
B
C
R_2
R_4
D
1
-1
1
1
1
-1



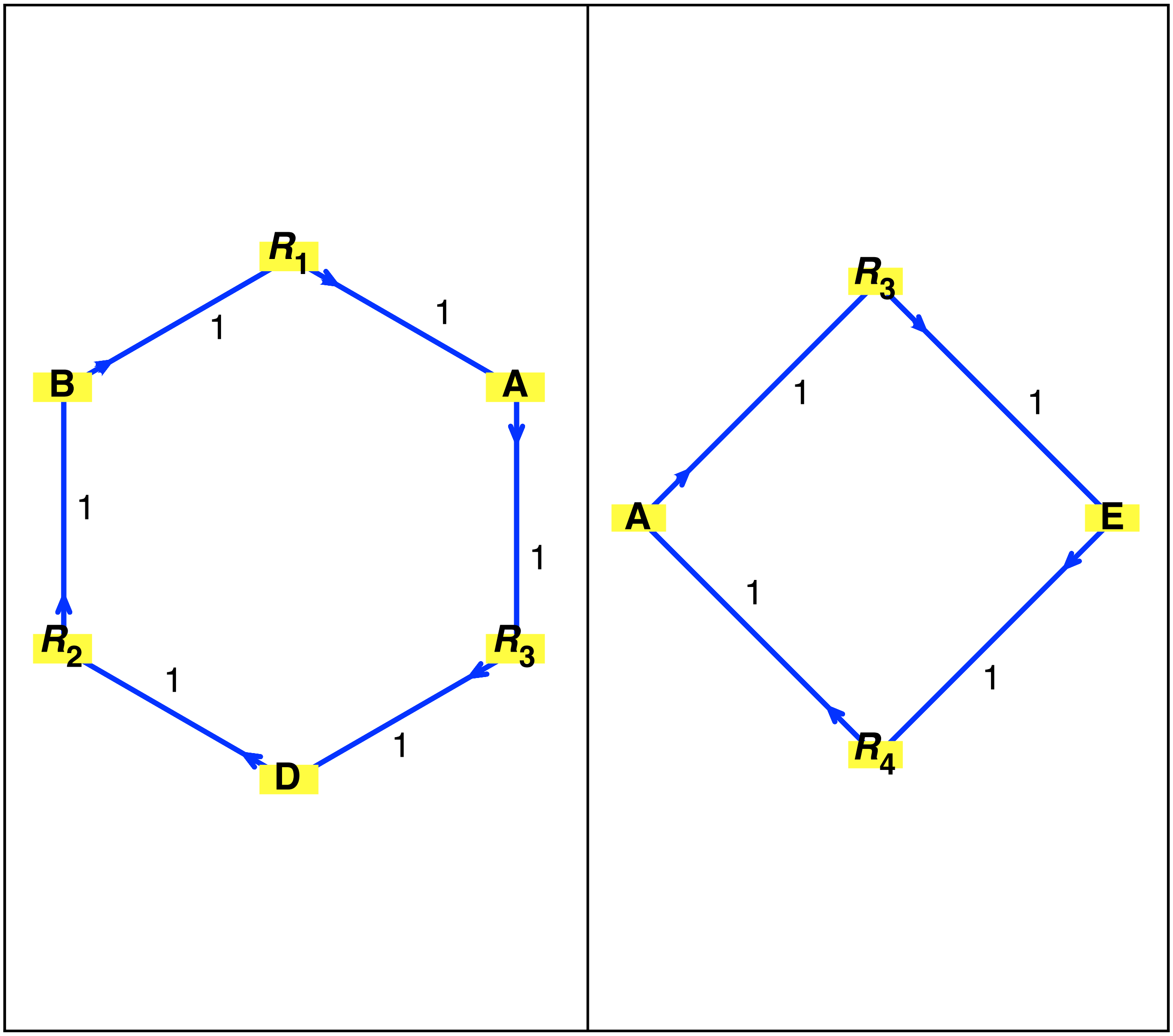
No. 57: injectiveEx3_3009.csv



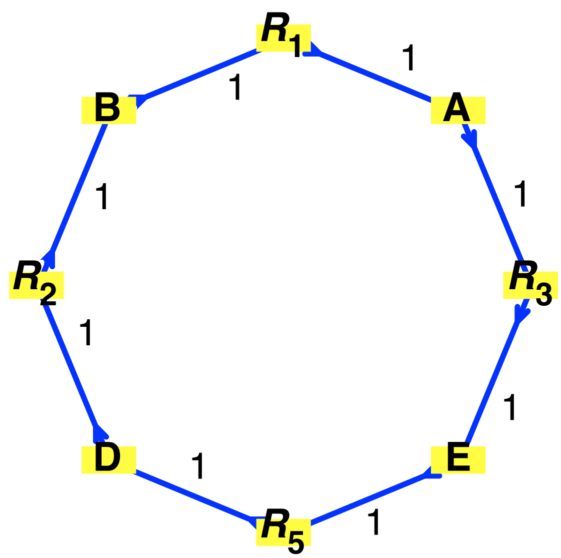
R1
B
A
R2
R3
D
1
1
1
1
1
1
R1
B
A
R2
R3
D
E
R5
1
1
1
1
1
1
1
1



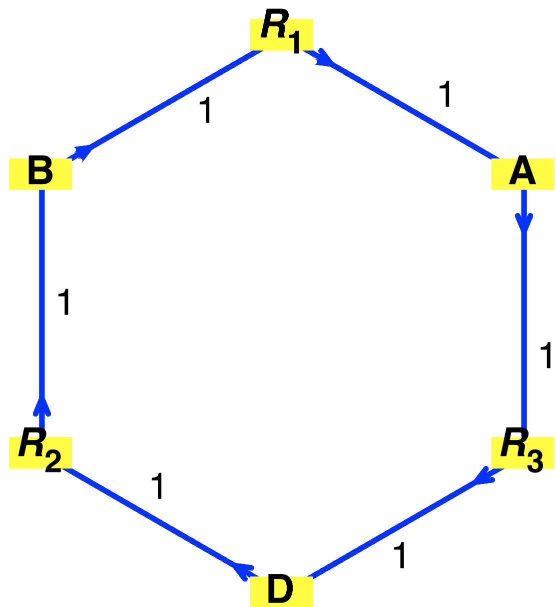
No. 58: injectiveEx3_3011.csv

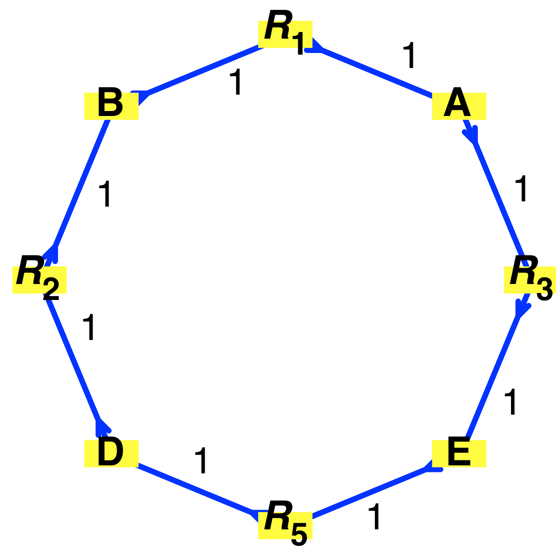


R_1
1
1
B
A
1
1
R_2
R_3
1
1
D
R_3
1
1
A
E
1
1
R_4

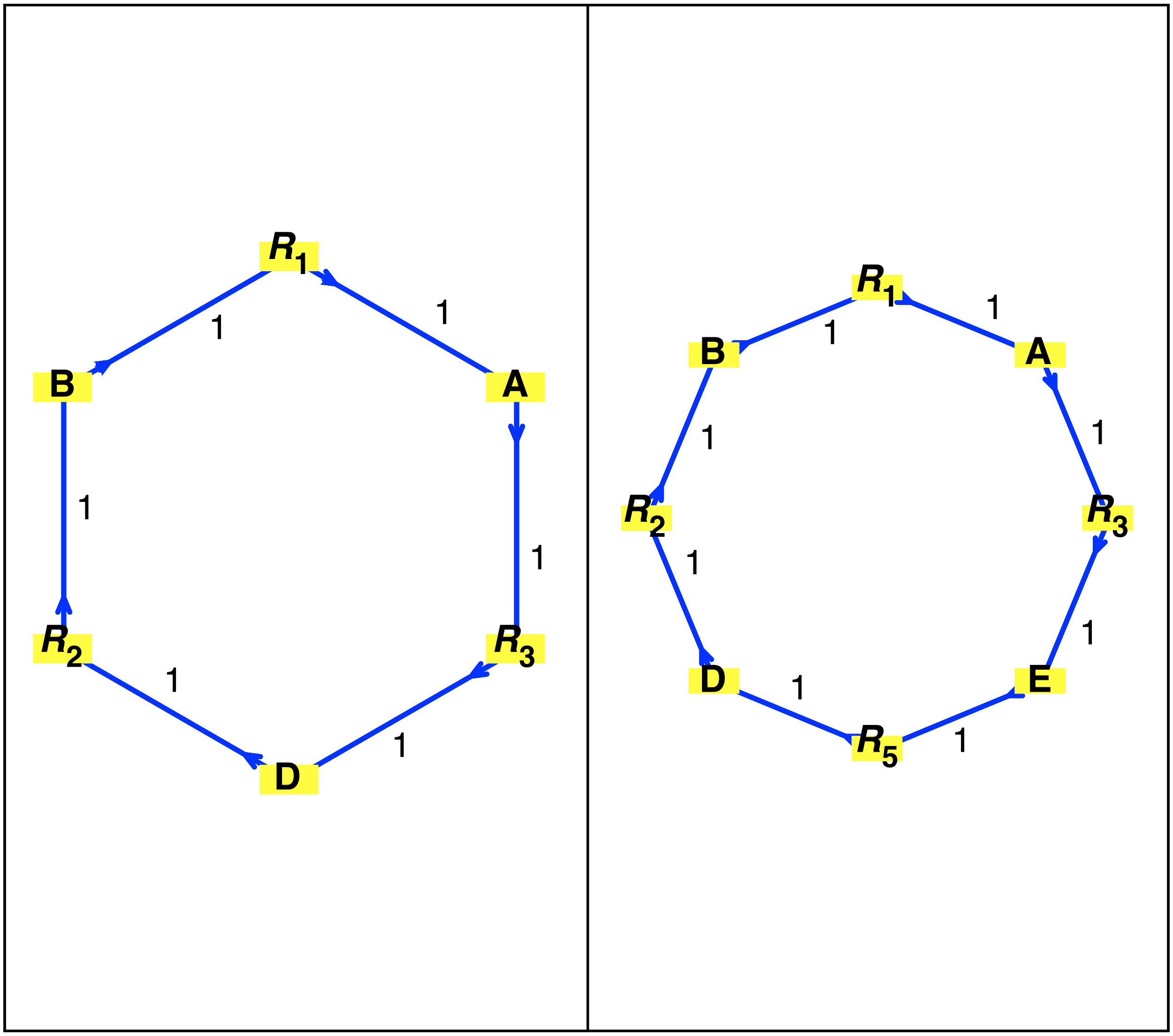


No. 59: injectiveEx3_3012.csv

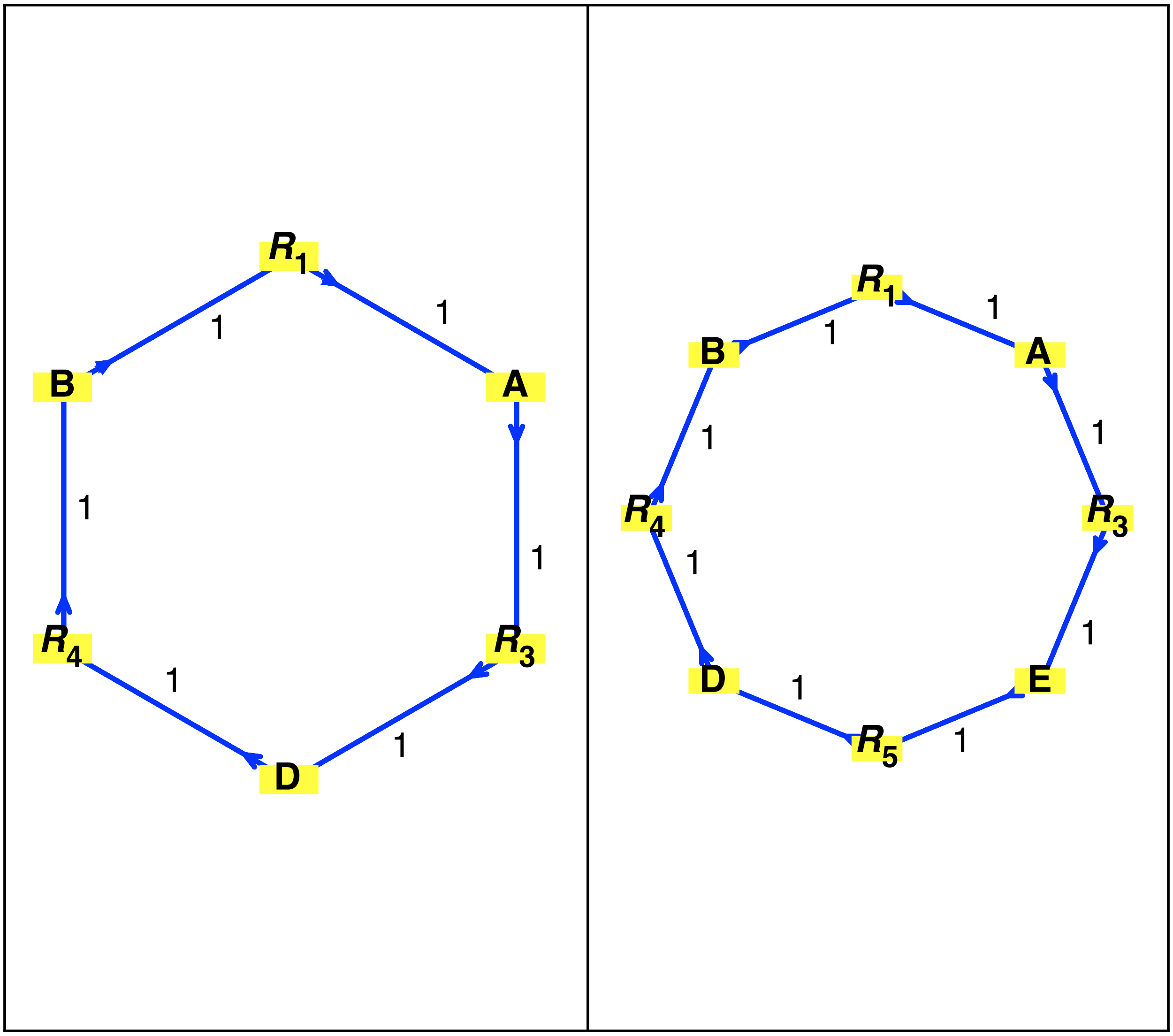




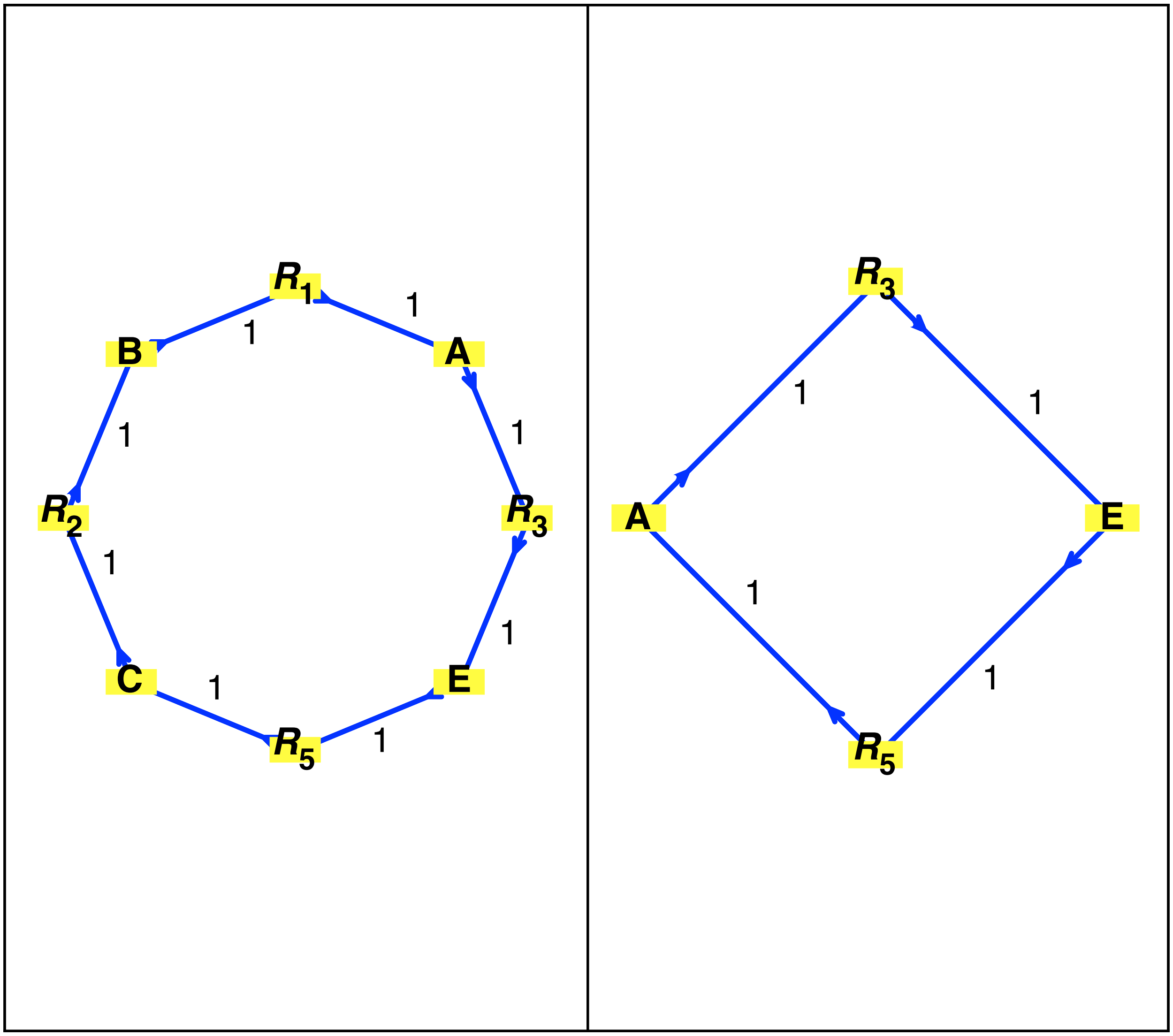
No. 60: injectiveEx3_3014.csv



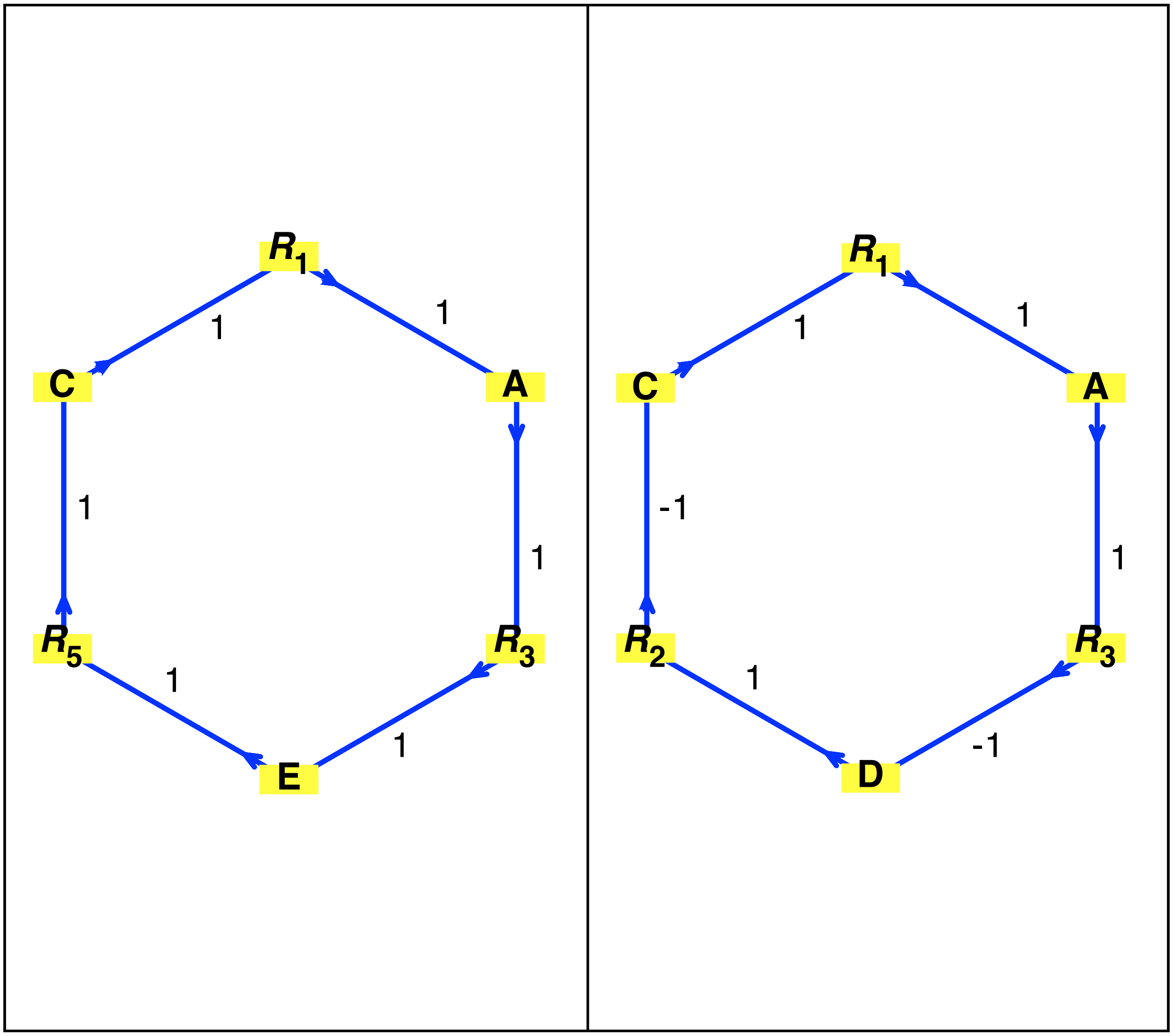
R_1
B
A
R_2
R_3
D
1
1
1
1
1
1
R_1
B
A
R_2
R_3
D
E
R_5
1
1
1
1
1
1
1
1



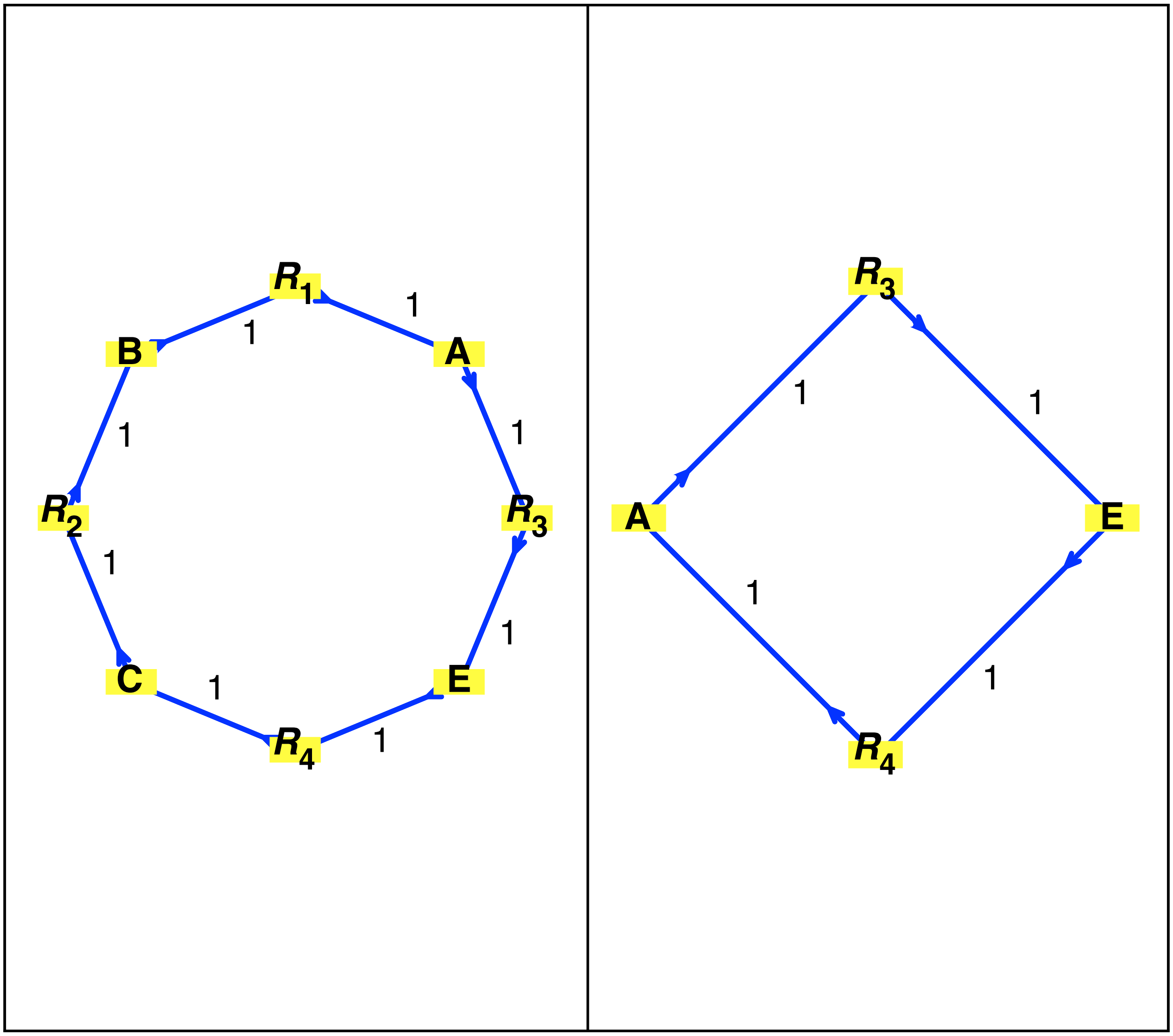
No. 61: injectiveEx3_3015.csv

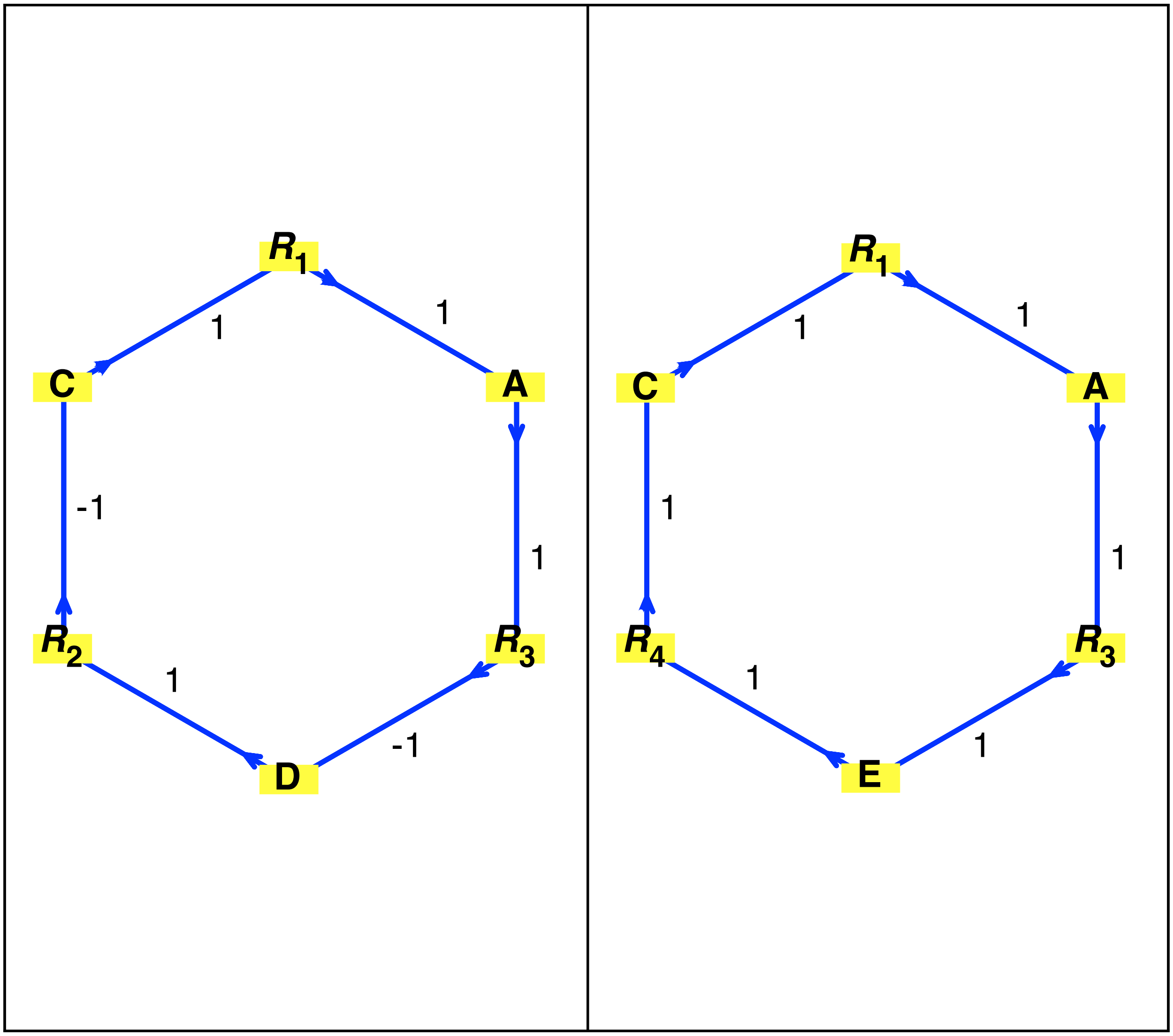


R_1
B
A
R_2
R_3
C
E
R_5
1
1
1
1
1
1
1
1
R_3
A
E
R_5
1
1
1
1

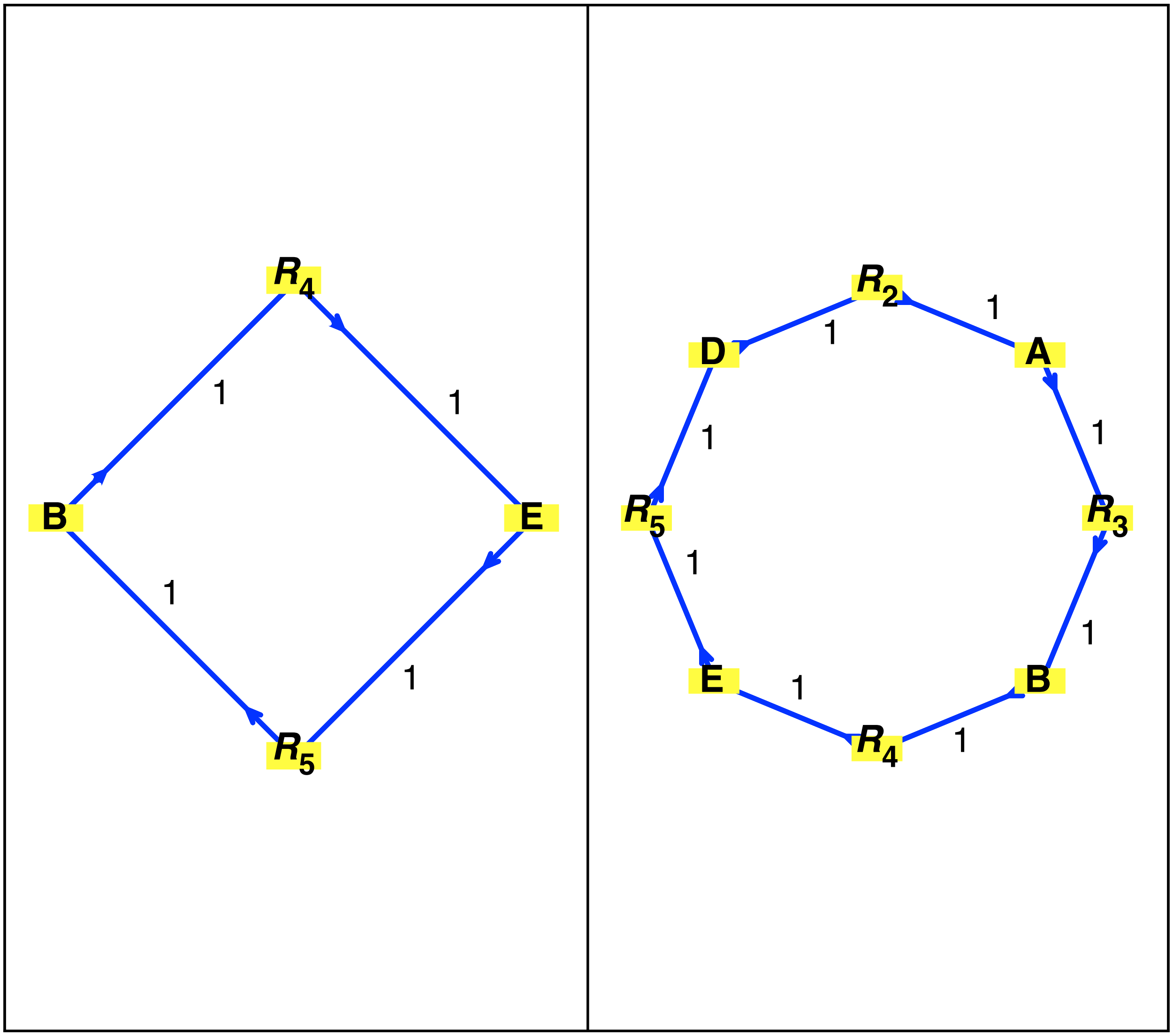


No. 62: injectiveEx3_3017.csv

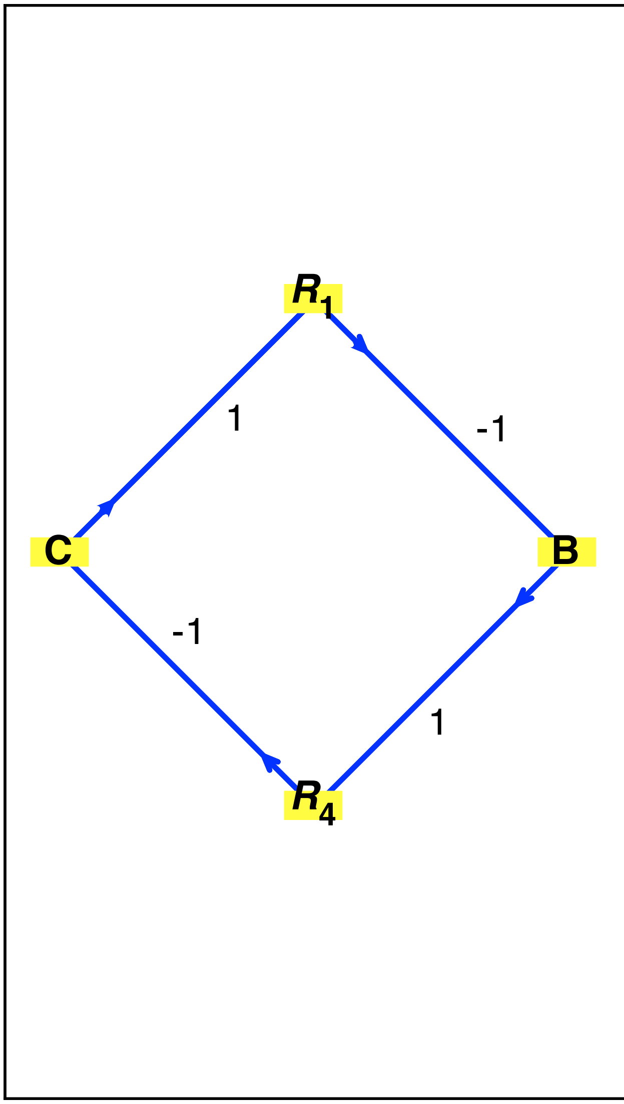

R_1
B
A
R_2
R_3
C
E
R_4
1
1
1
1
1
1
1
1
R_3
A
E
R_4
1
1
1
1

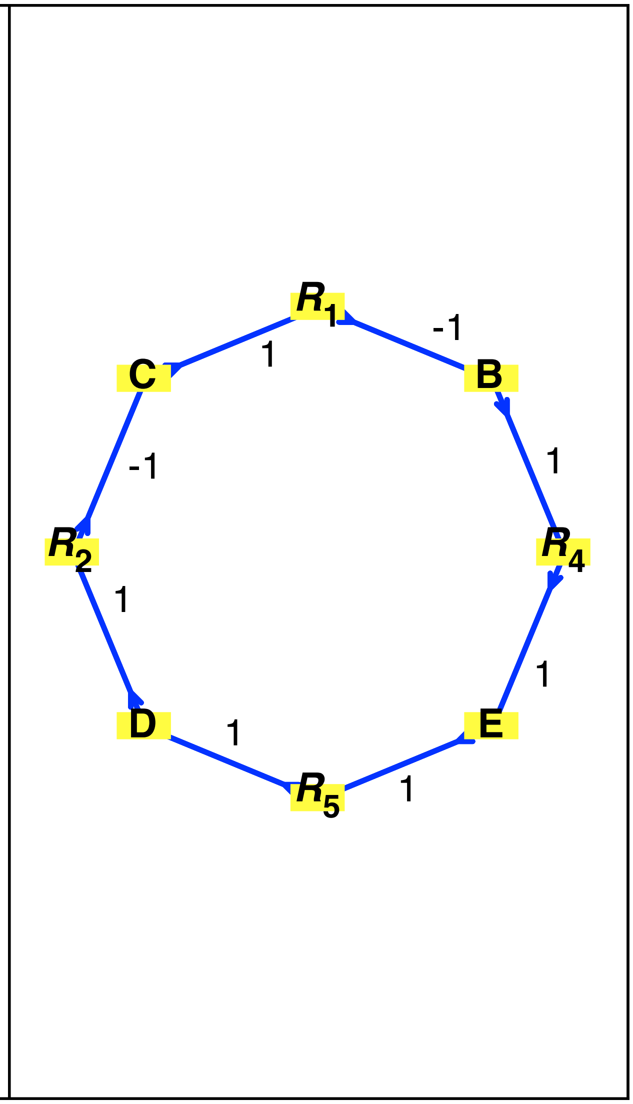


No. 63: injectiveEx3_3110.csv

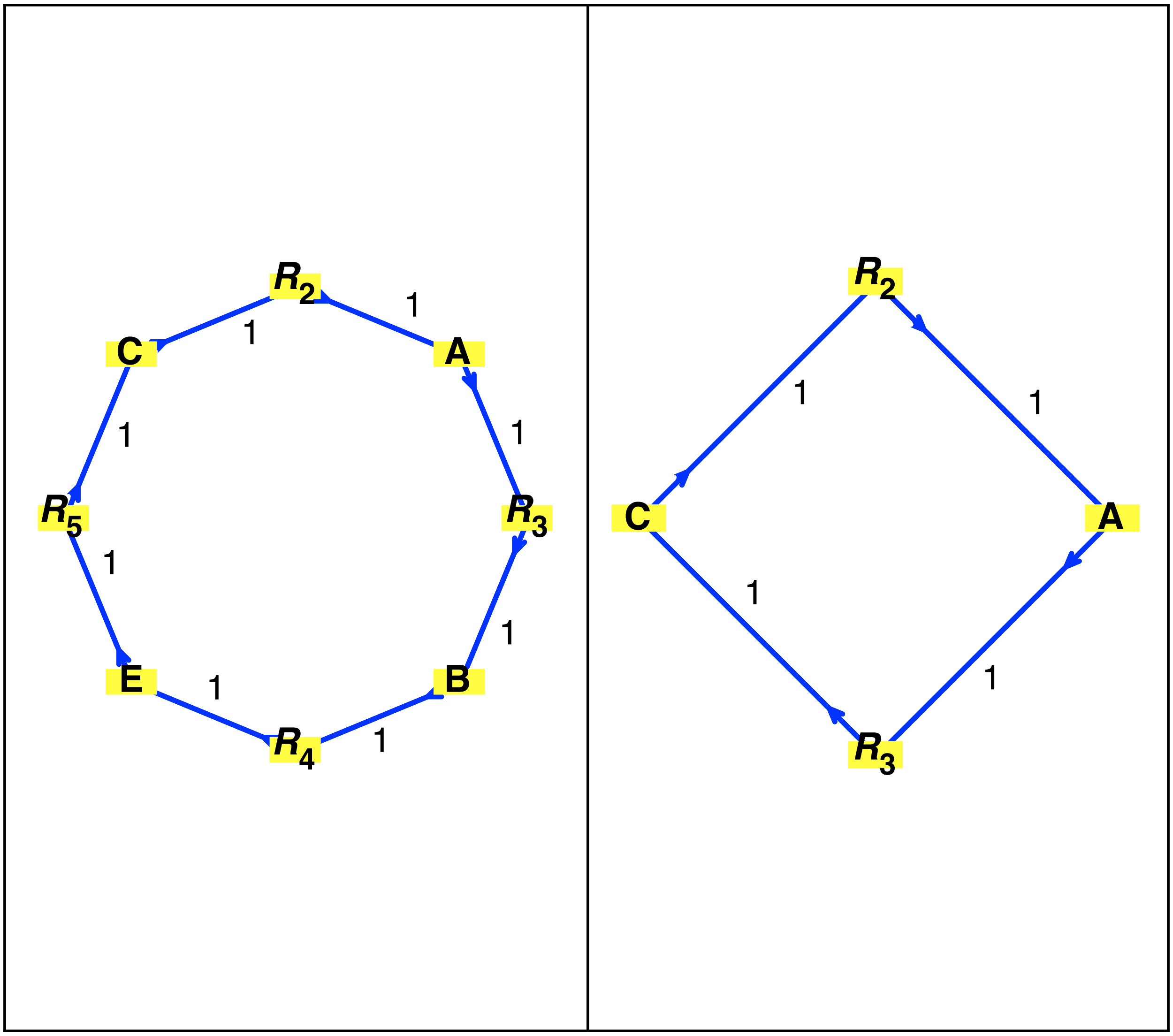


R_4
B
E
R_5
1
1
1
1
R_2
D
A
R_5
R_3
E
B
R_4
1
1
1
1
1
1
1
1

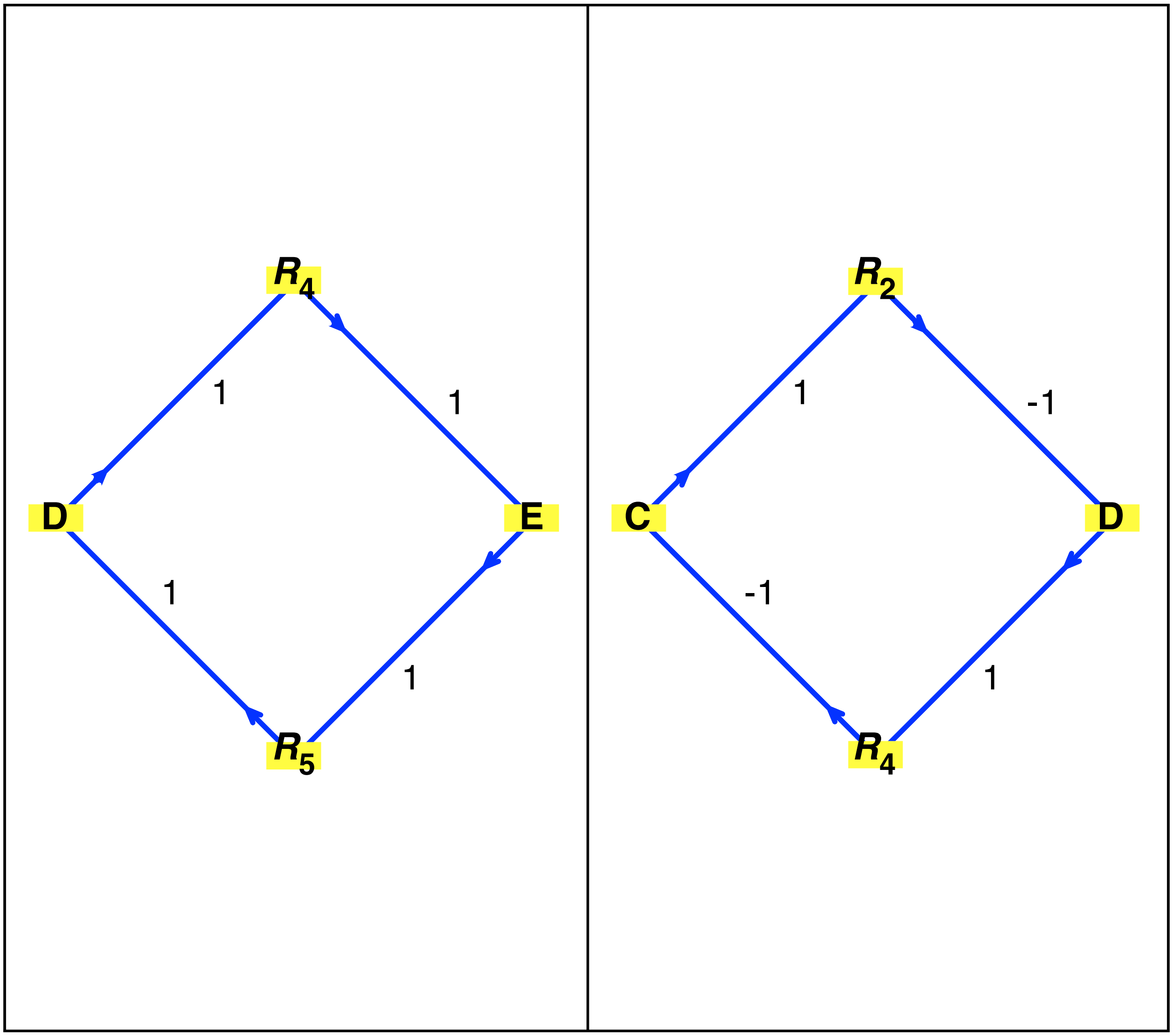




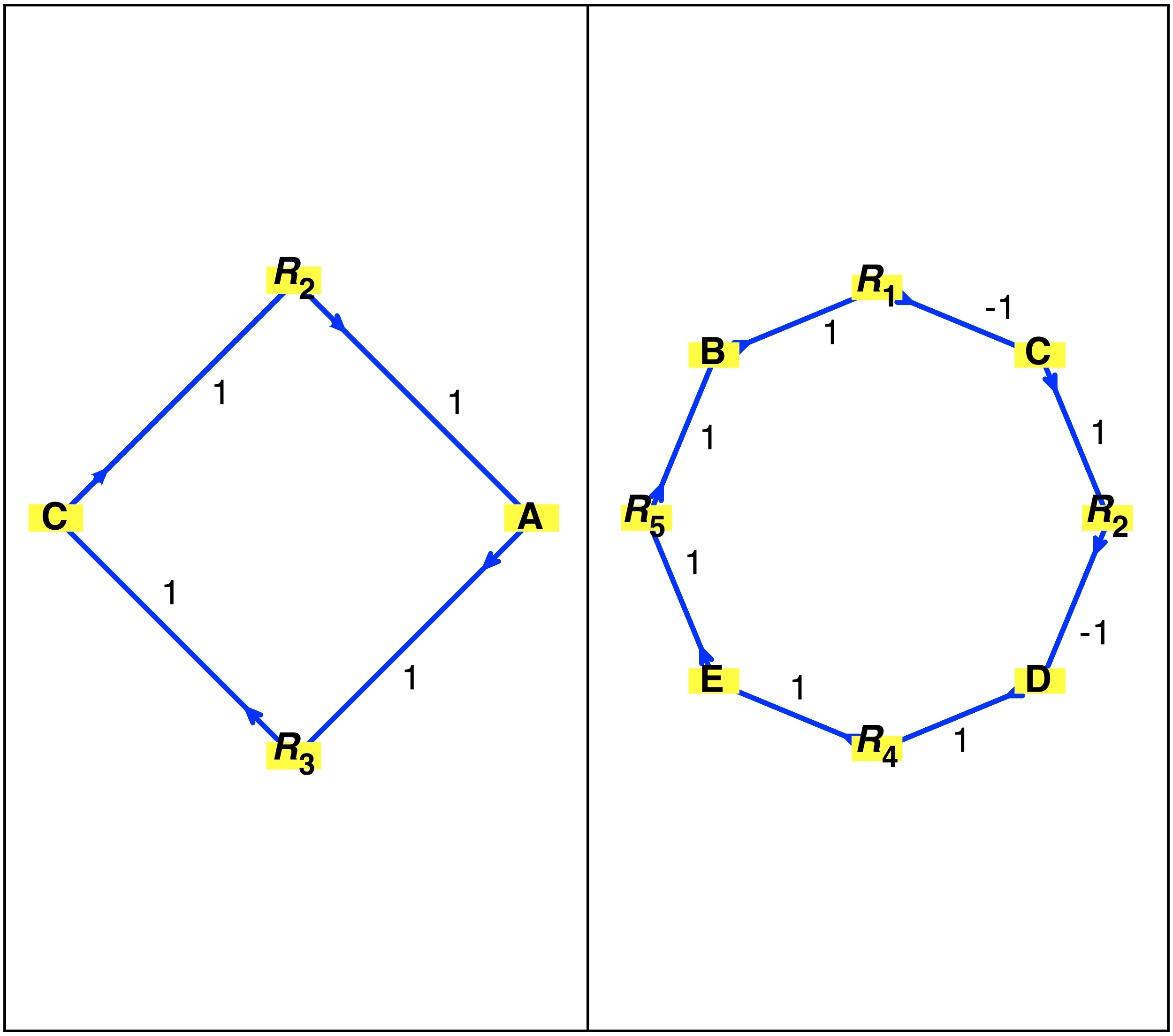
No. 64: injectiveEx3_3114.csv



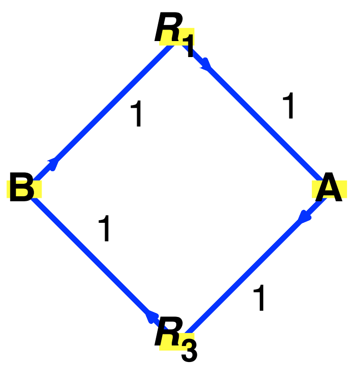
No. 65: injectiveEx3_3118.csv

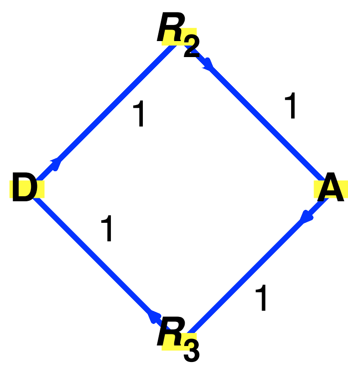


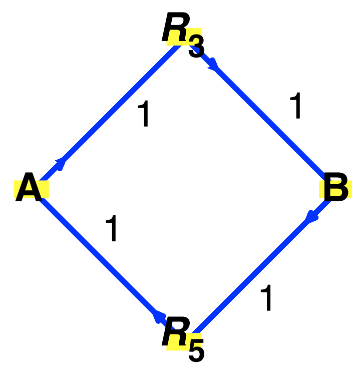
R_4
1
1
D
E
1
1
R_5
R_2
1
-1
C
D
-1
1
R_4

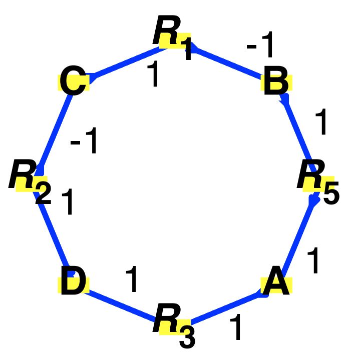


No. 66: injectiveEx3_3123.csv

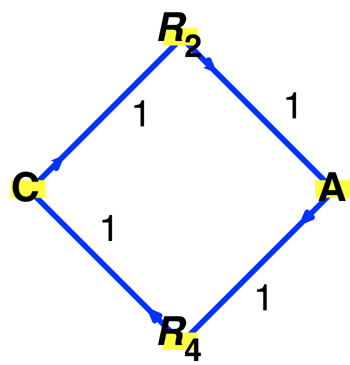

R_1
B
A
R_3
1
1
1
1


R_2
D
A
R_3
1
1
1
1

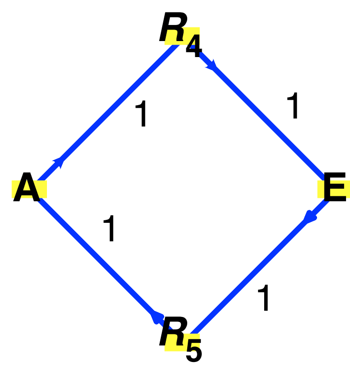

R_3
A
B
R_5
1
1
1
1



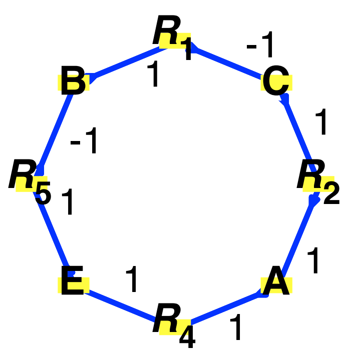
R1
-1
C
1
B
1
-1
R2
R5
1
D
1
A
1
R3
1

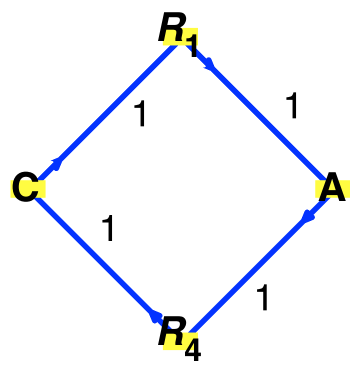


R2
1
1
C
A
1
1
R4

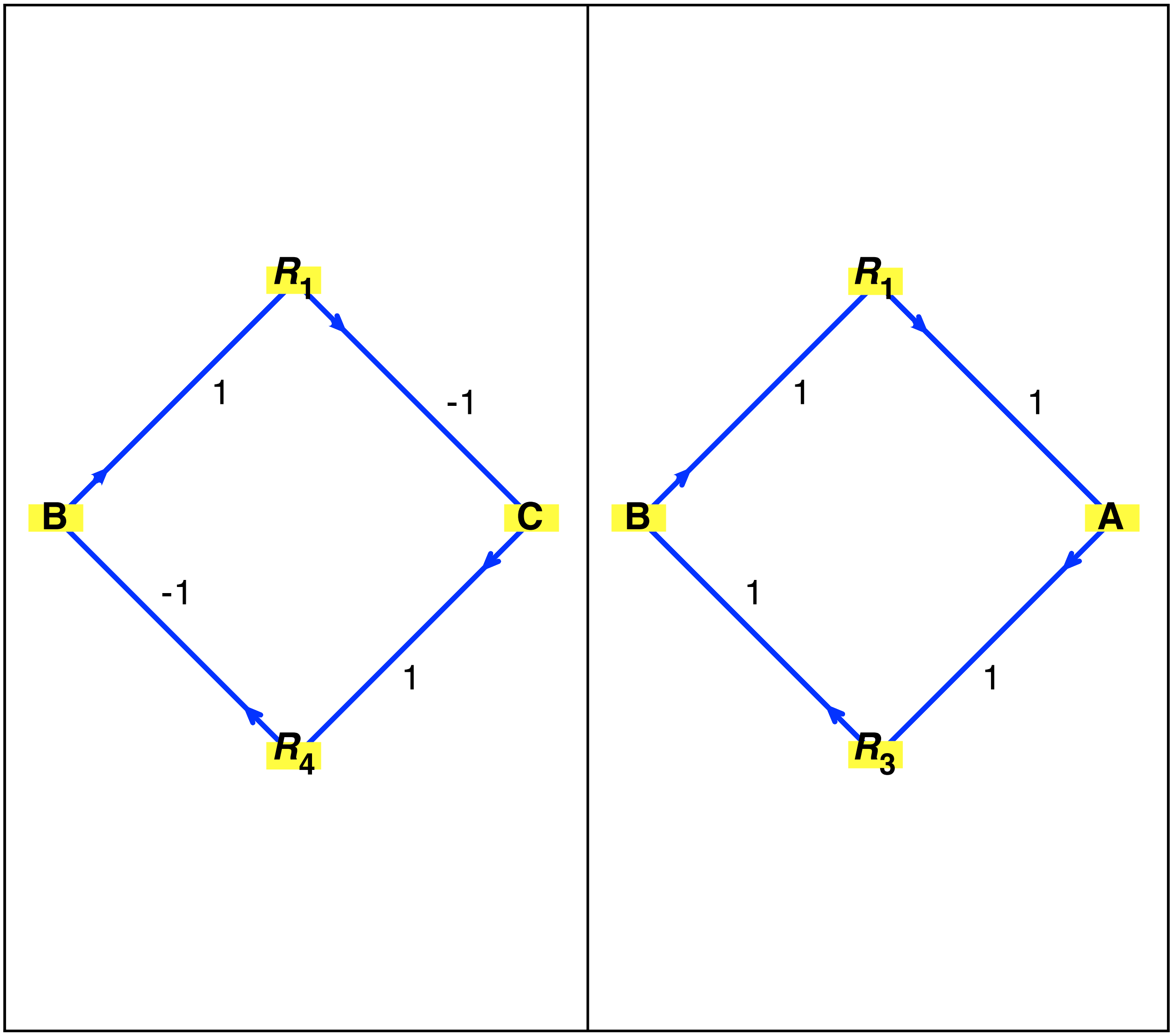


R4
1
1
A
E
1
1
R5

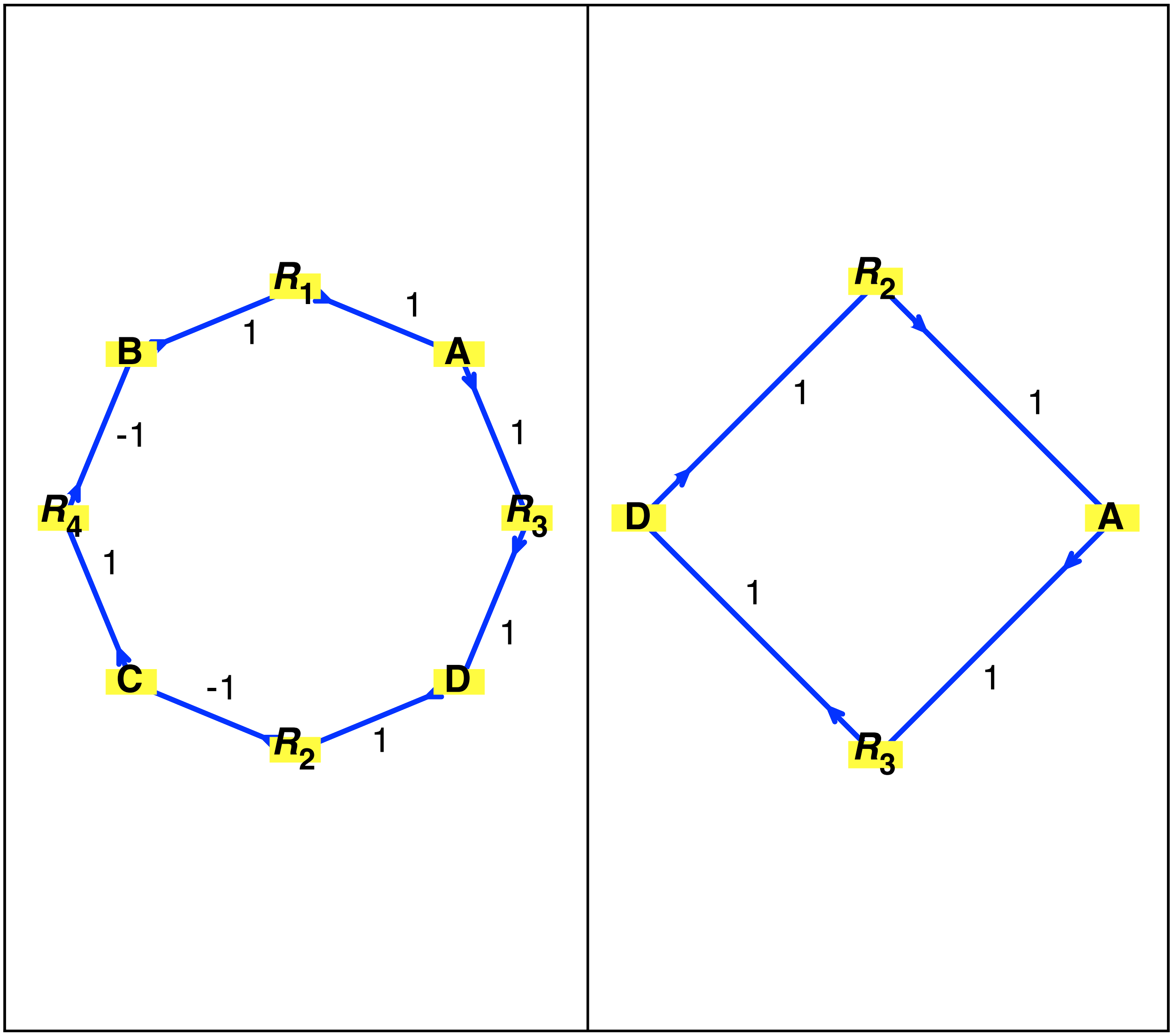




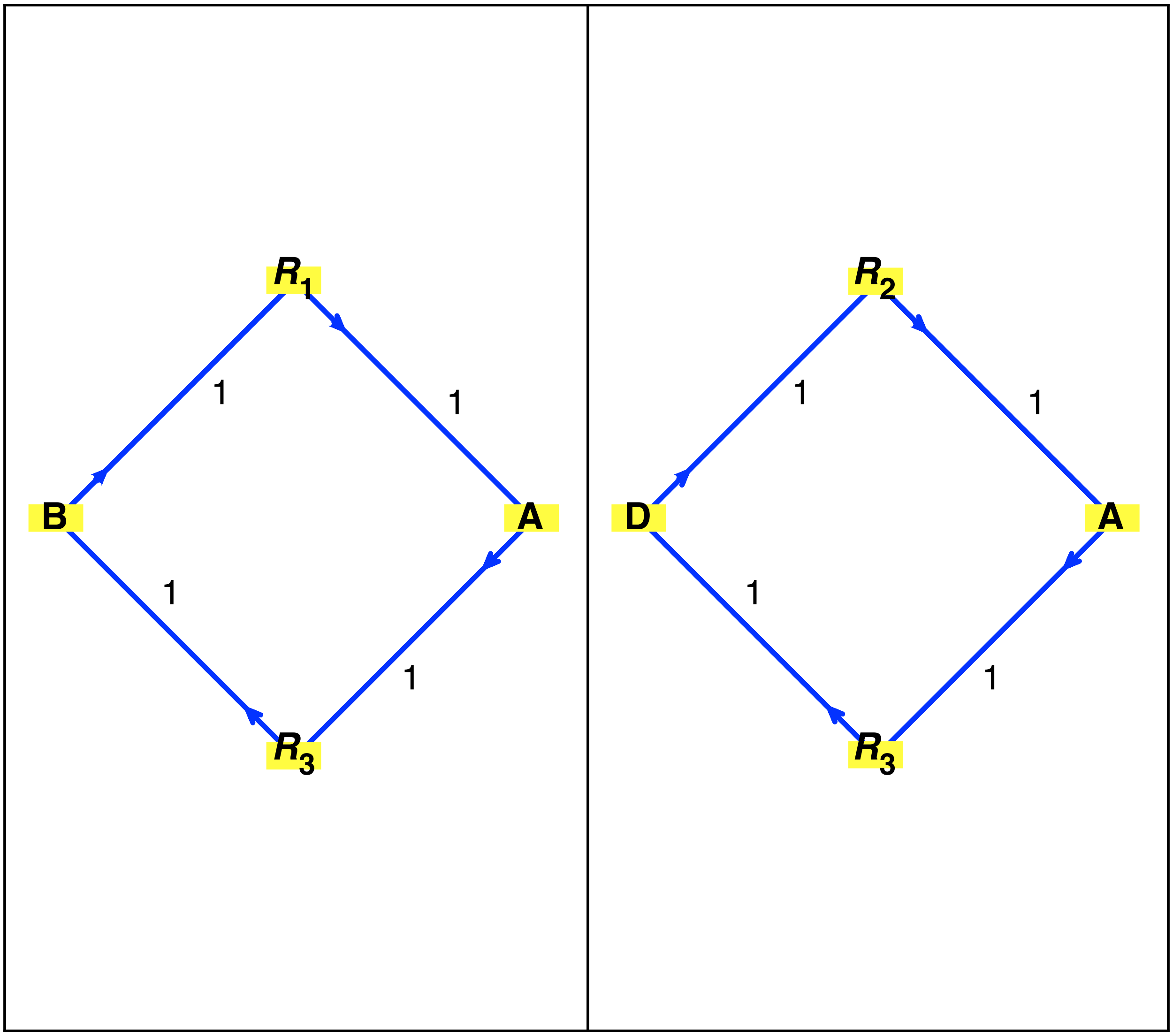
No. 67: injectiveEx3_3128.csv



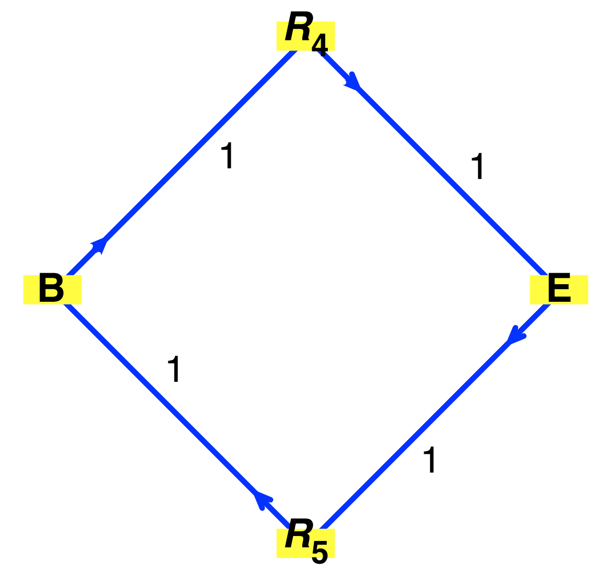
R_1
1
-1
B
C
-1
1
R_4
R_1
1
1
B
A
1
1
R_3

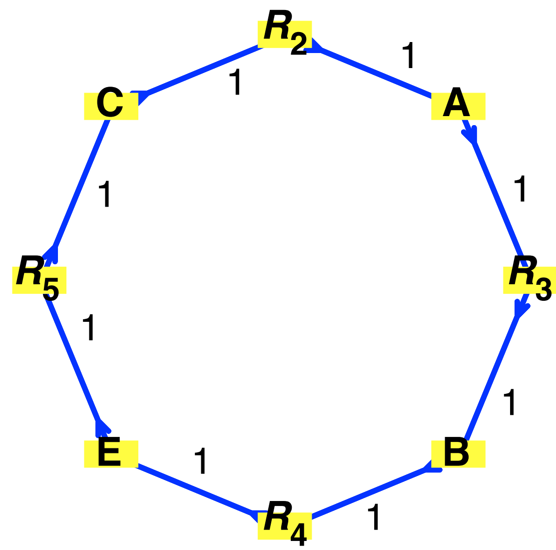


No. 68: injectiveEx3_3130.csv

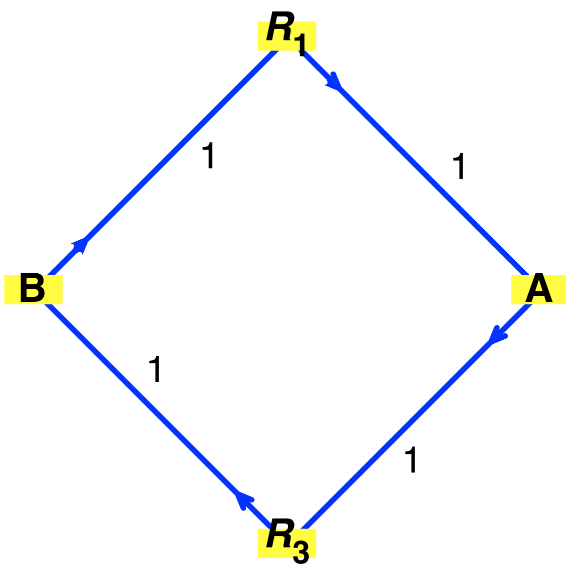
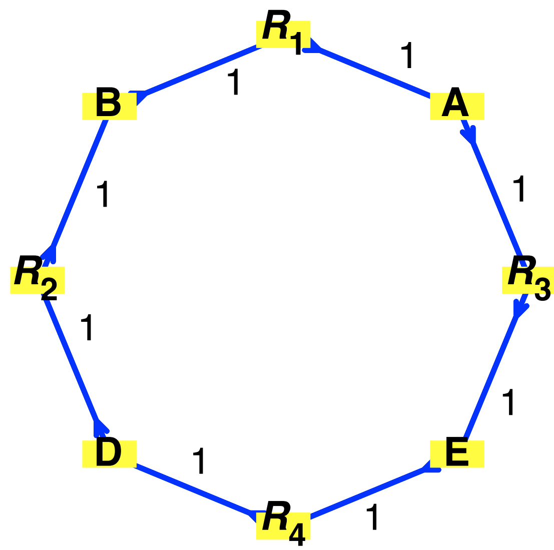


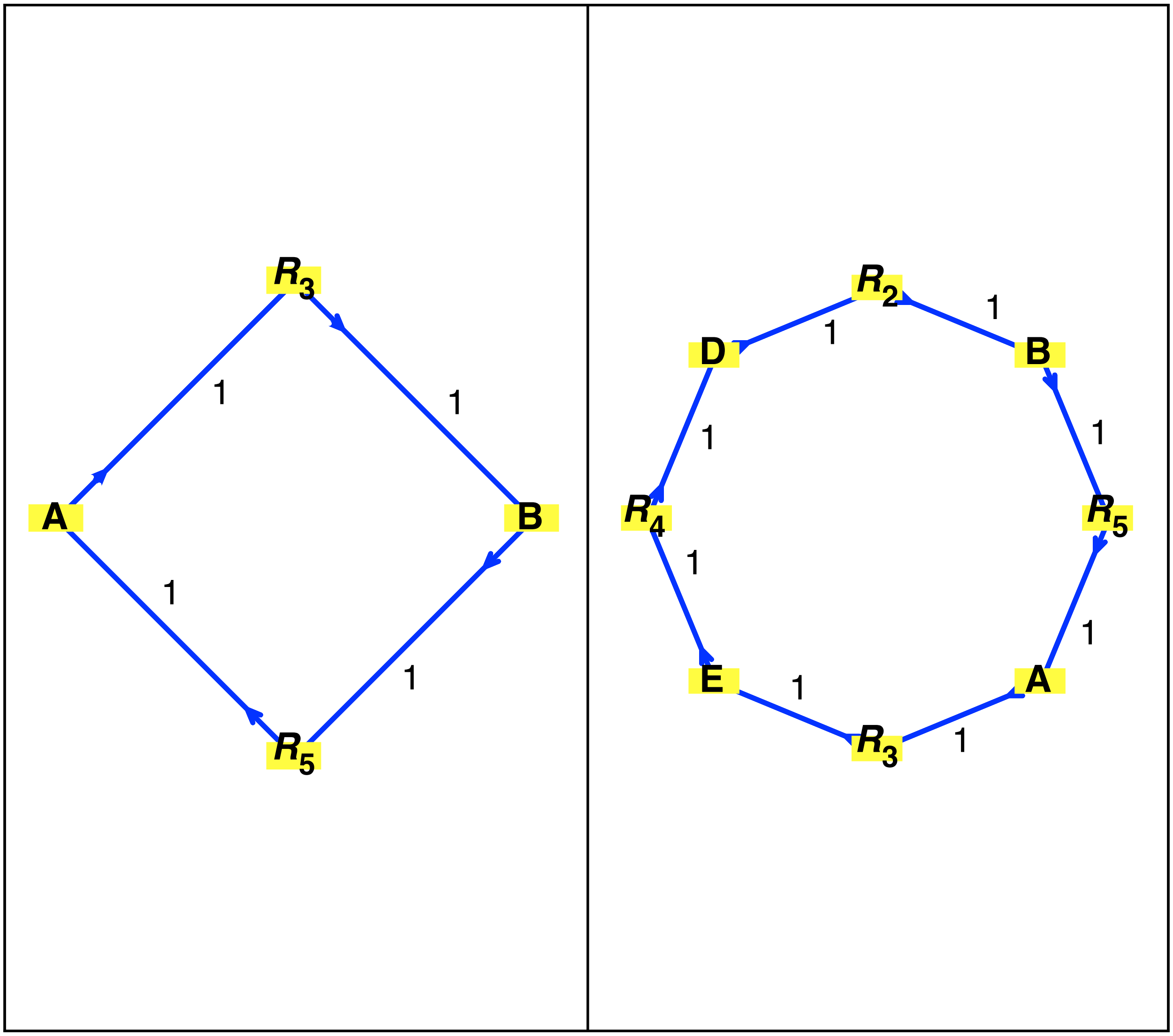
R_1
1
1
B
A
1
1
R_3
R_2
1
1
D
A
1
1
R_3



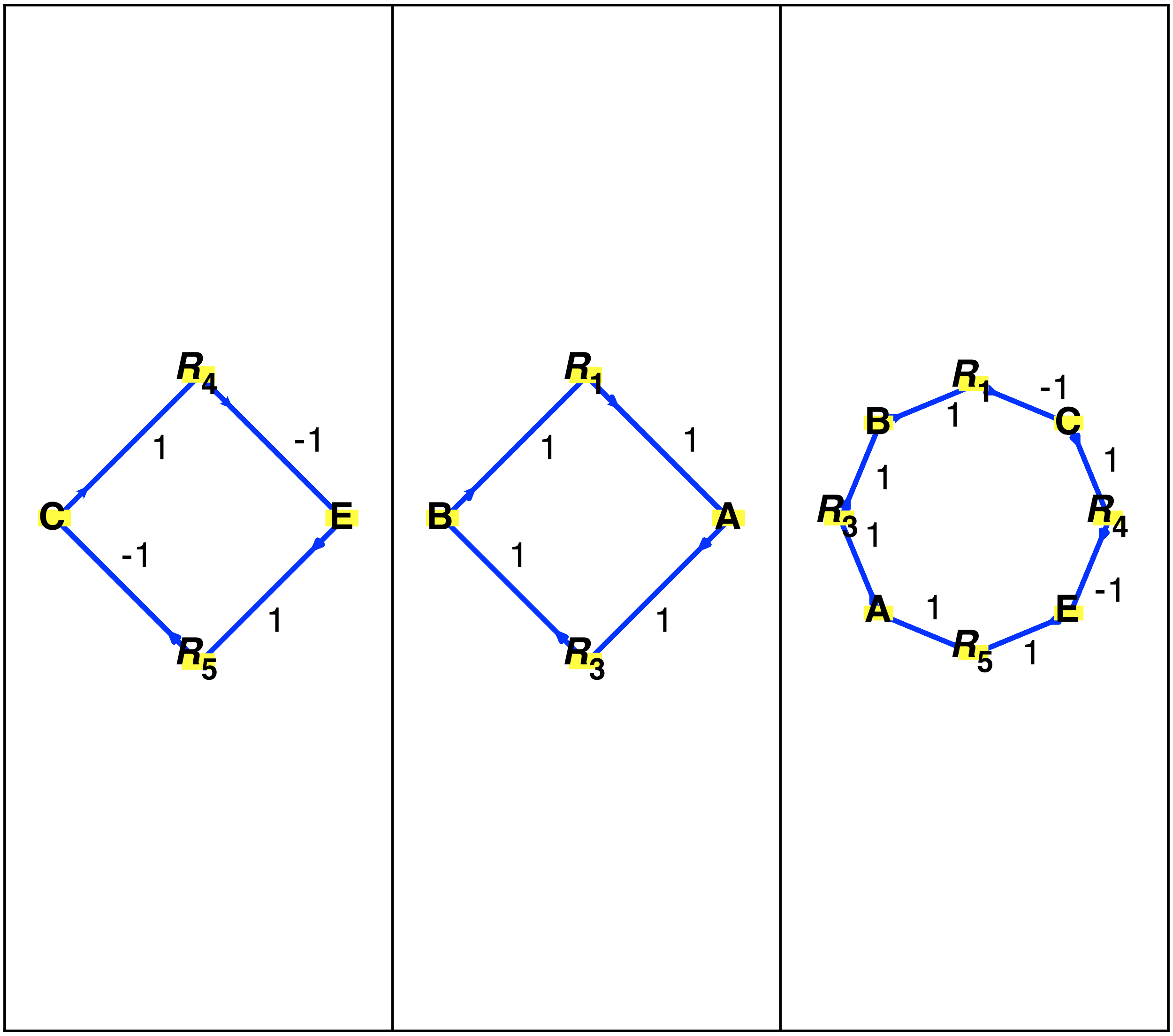


No. 69: injectiveEx3_3553.csv

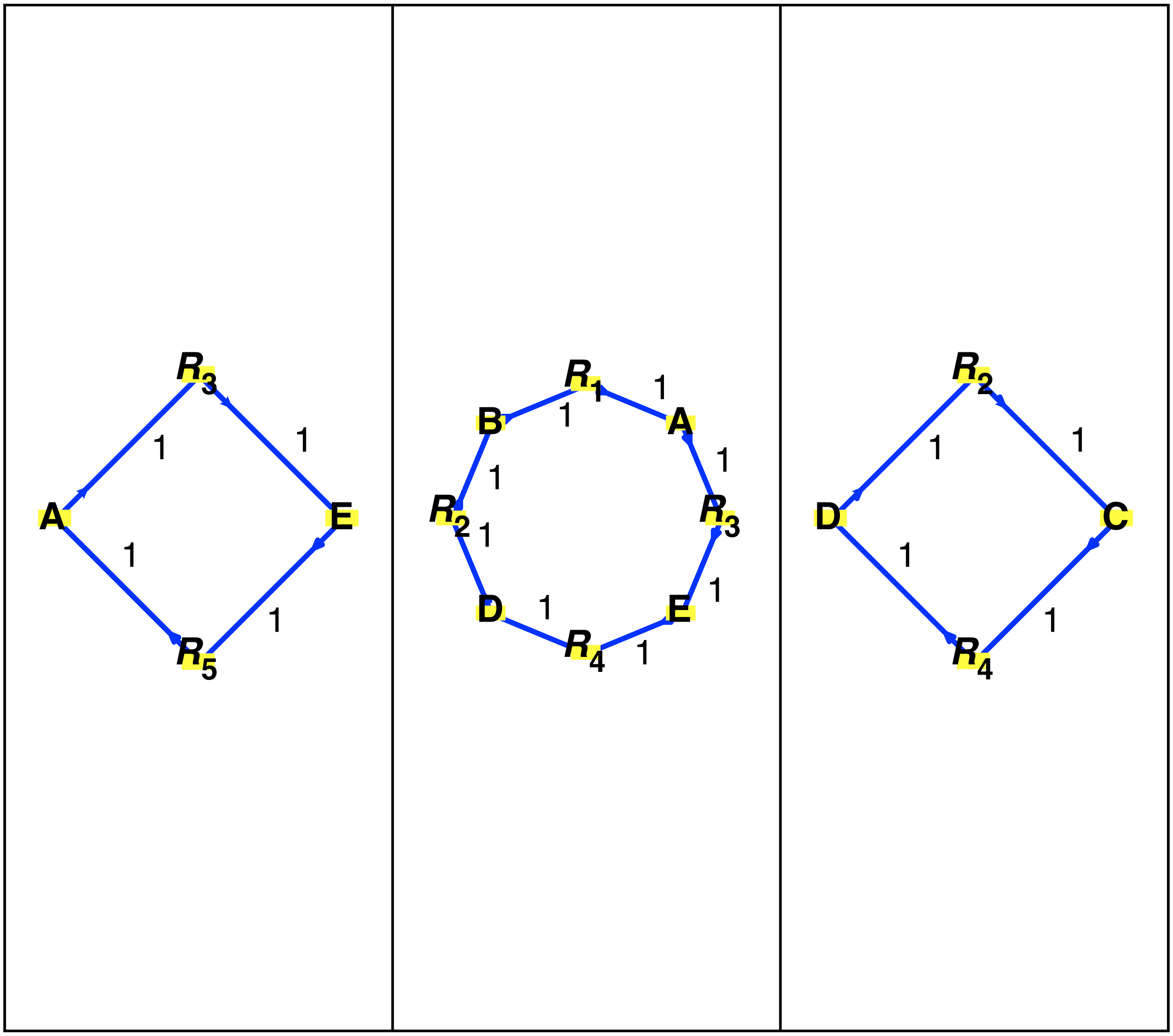
| R_1
B
A
R_3
1
1
1
1 | R_1
B
A
R_2
R_3
D
E
R_4
1
1
1
1
1
1
1
1 |
| --- | --- |



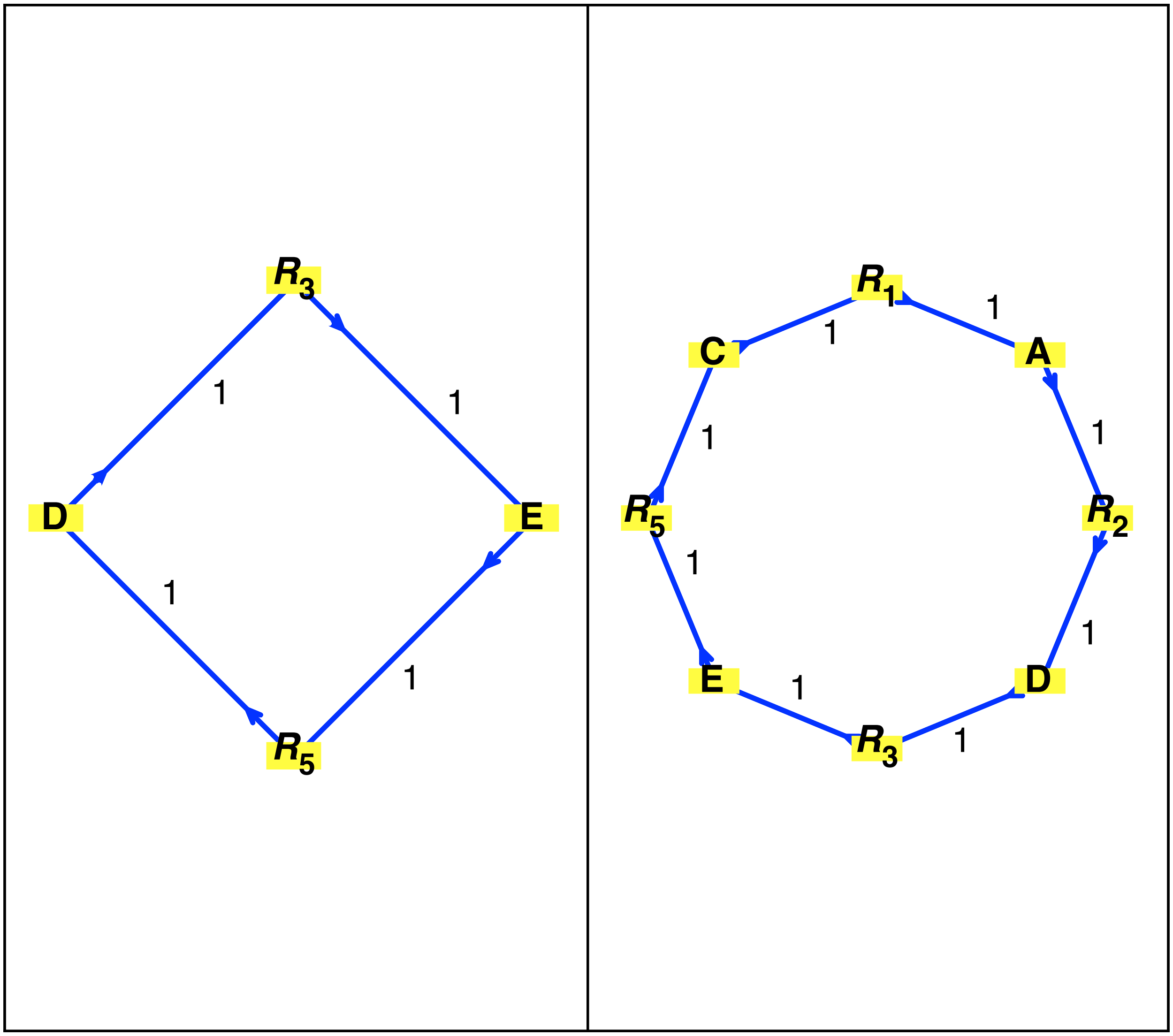
No. 70: injectiveEx3_3555.csv



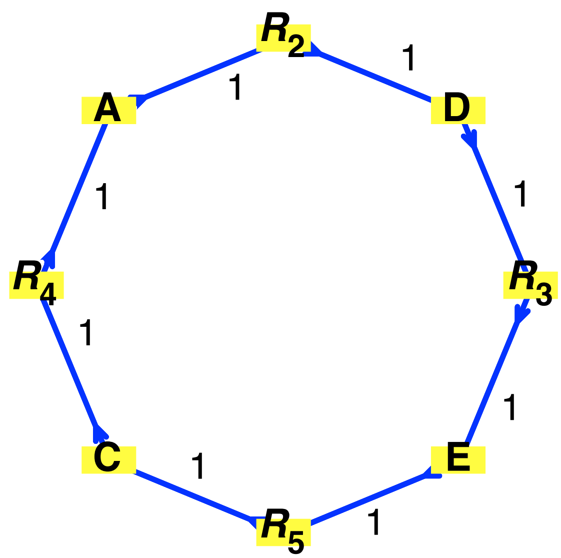
R_4
-1
1
C
E
-1
1
R_5
R_1
1
1
B
A
1
1
R_3
R_1
-1
B
1
C
1
1
R_3
R_4
1
A
1
E
-1
R_5
1



No. 71: injectiveEx3_4324.csv



R_3
D
E
R_5
1
1
1
1
R_1
C
A
R_5
R_2
E
D
R_3
1
1
1
1
1
1
1
1



R2
A
D
R4
R3
C
E
R5
1
1
1
1
1
1
1
1

>