

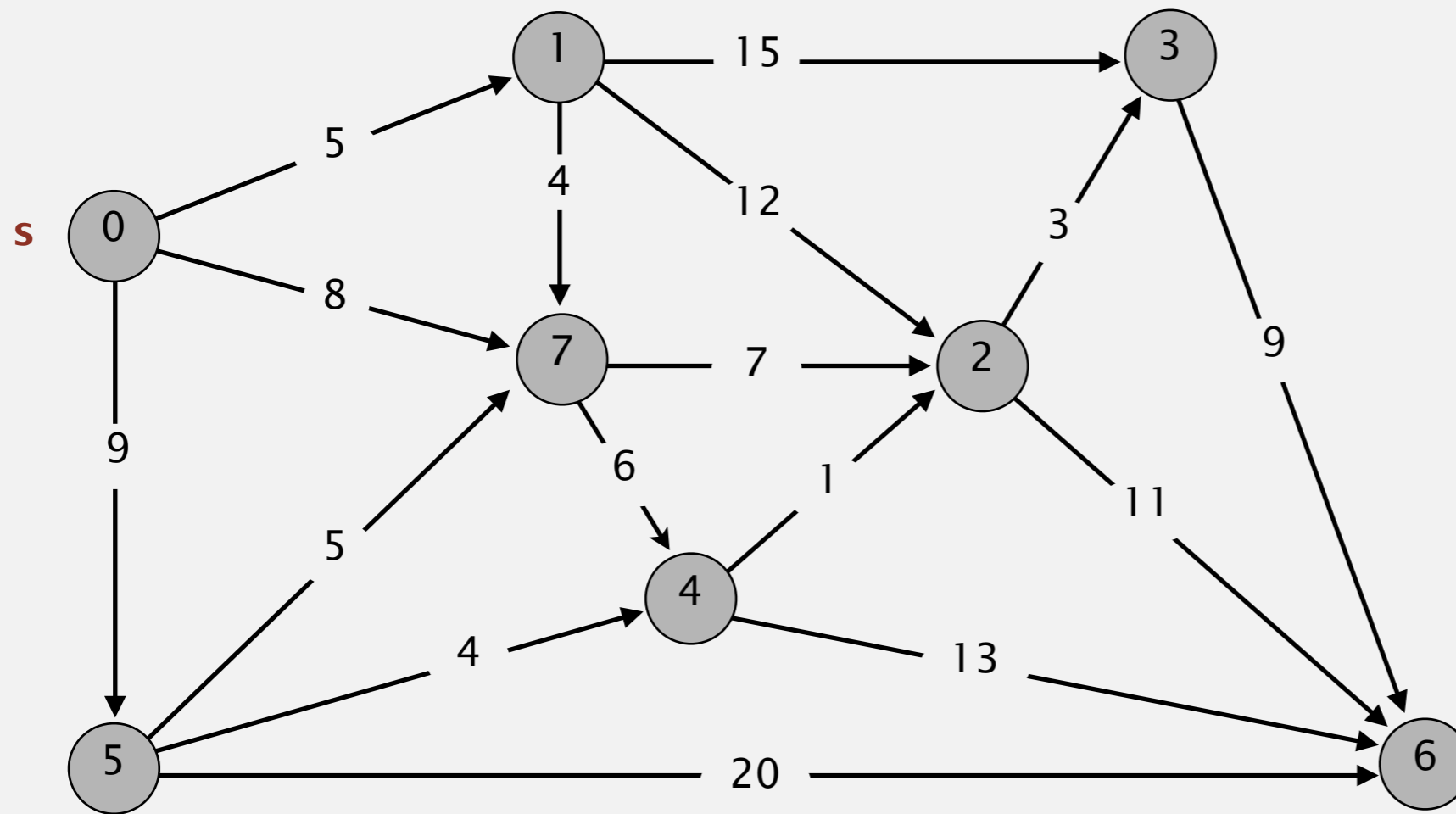


<https://algs4.cs.princeton.edu>

BELLMAN-FORD DEMO

Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.

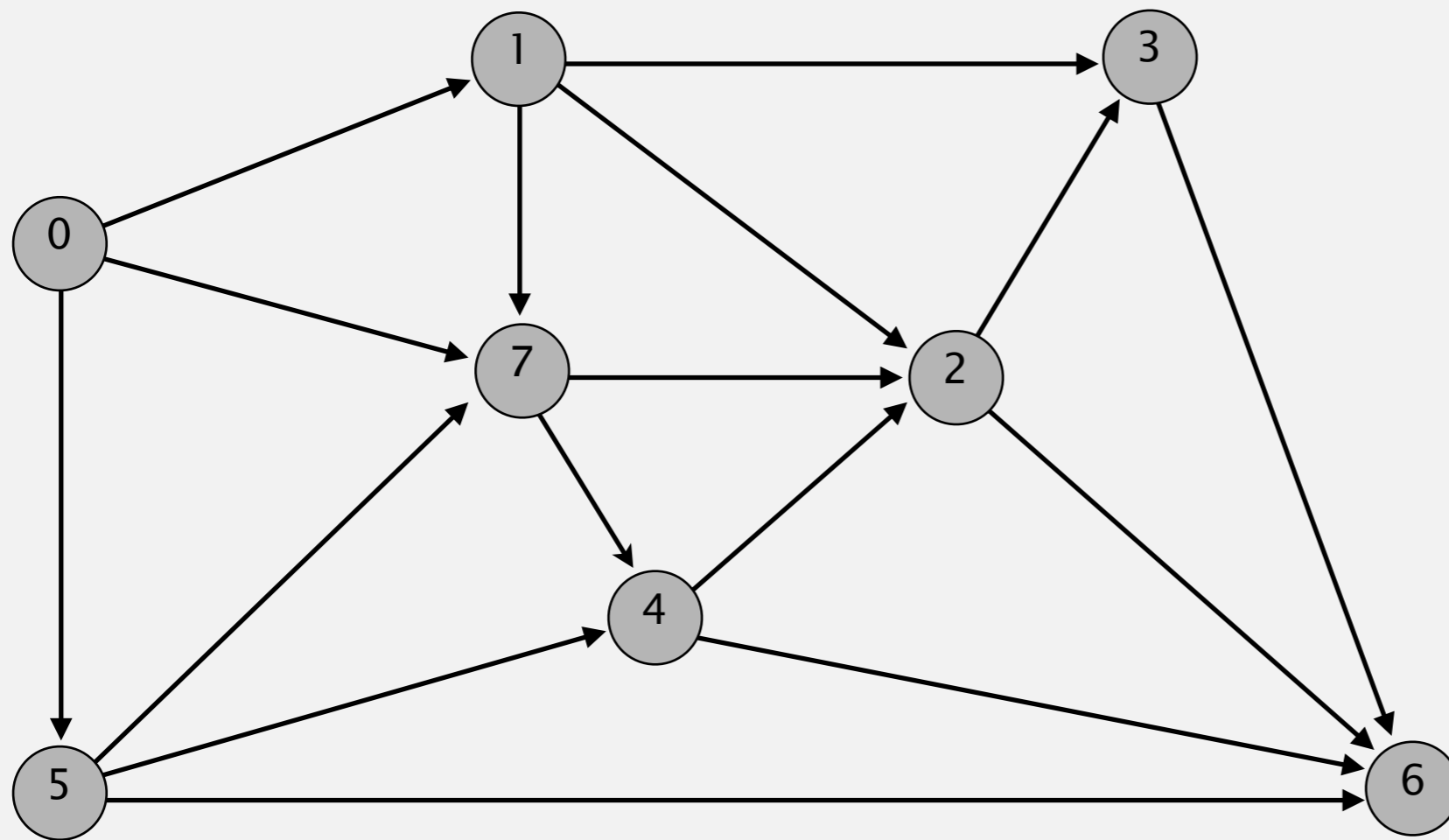


0→1	5.0
0→4	9.0
0→7	8.0
1→2	12.0
1→3	15.0
1→7	4.0
2→3	3.0
2→6	11.0
3→6	9.0
4→2	1.0
4→6	13.0
5→4	4.0
5→6	20.0
5→7	5.0
7→2	7.0
7→4	6.0

an edge-weighted digraph

Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.

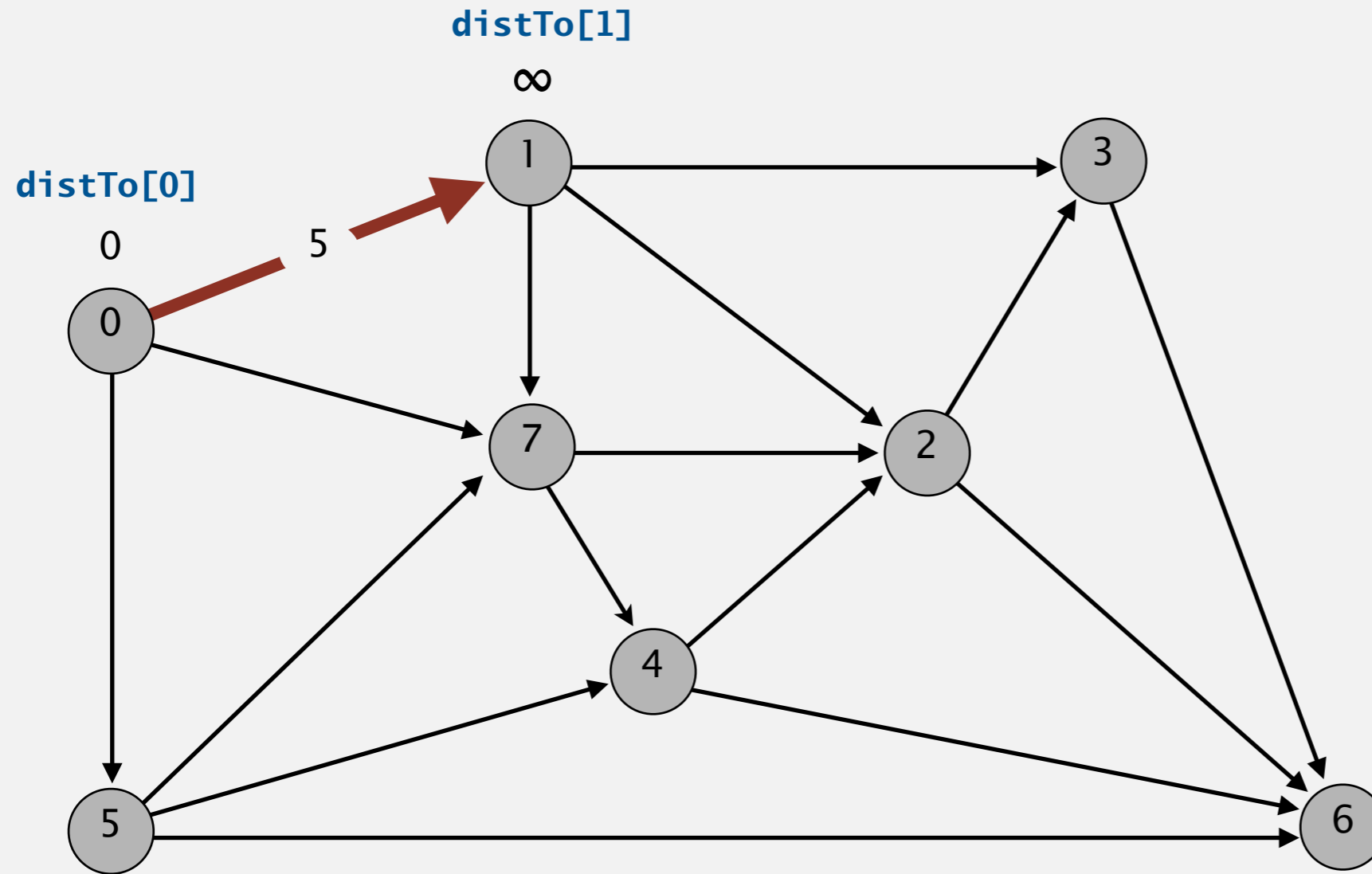


v	distTo[]	edgeTo[]
0	0.0	-
1		
2		
3		
4		
5		
6		
7		

initialize

Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1		
2		
3		
4		
5		
6		
7		

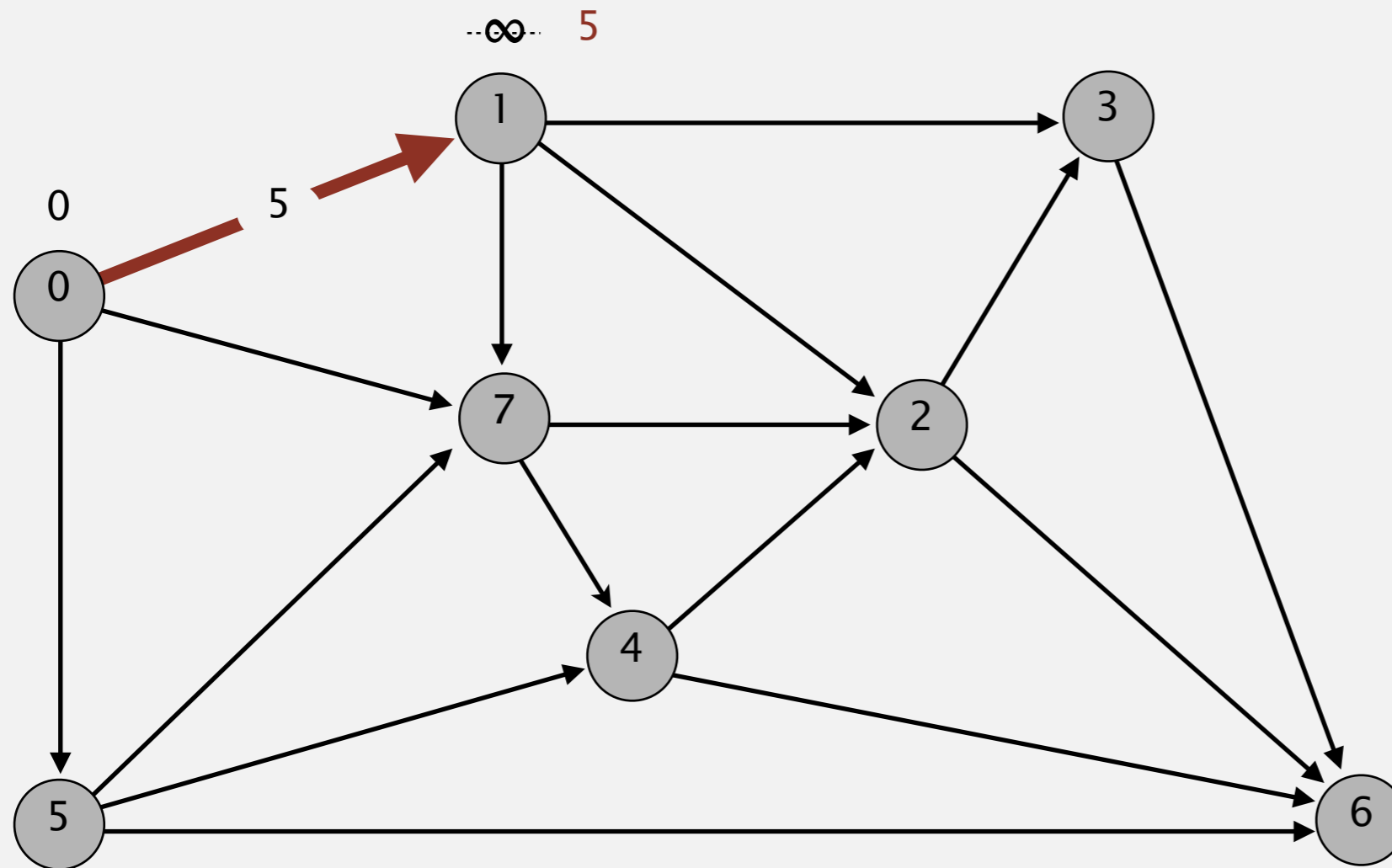
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2	∞	-
3	∞	-
4	∞	-
5	∞	-
6	∞	-
7	∞	-

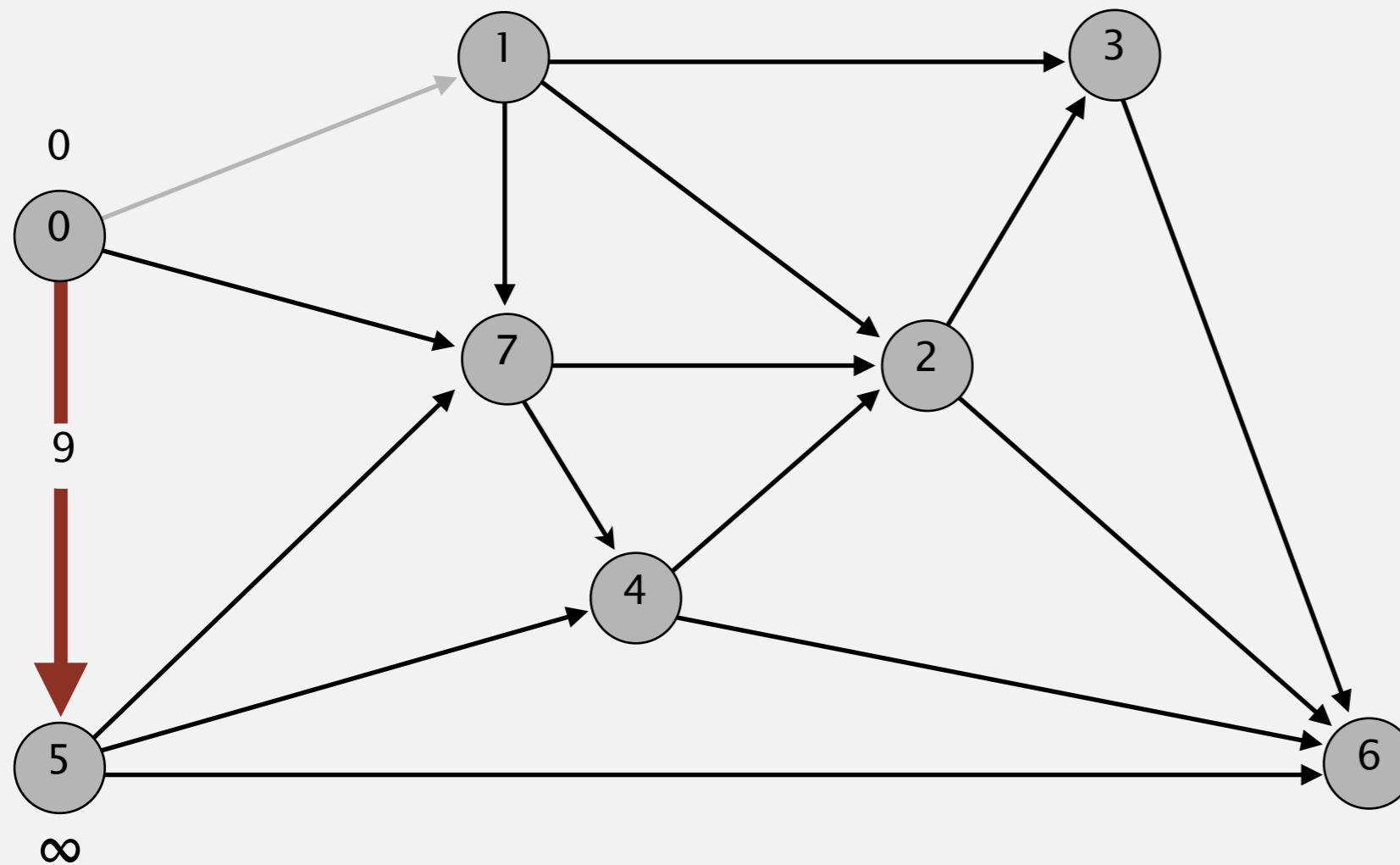
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2		
3		
4		
5		
6		
7		

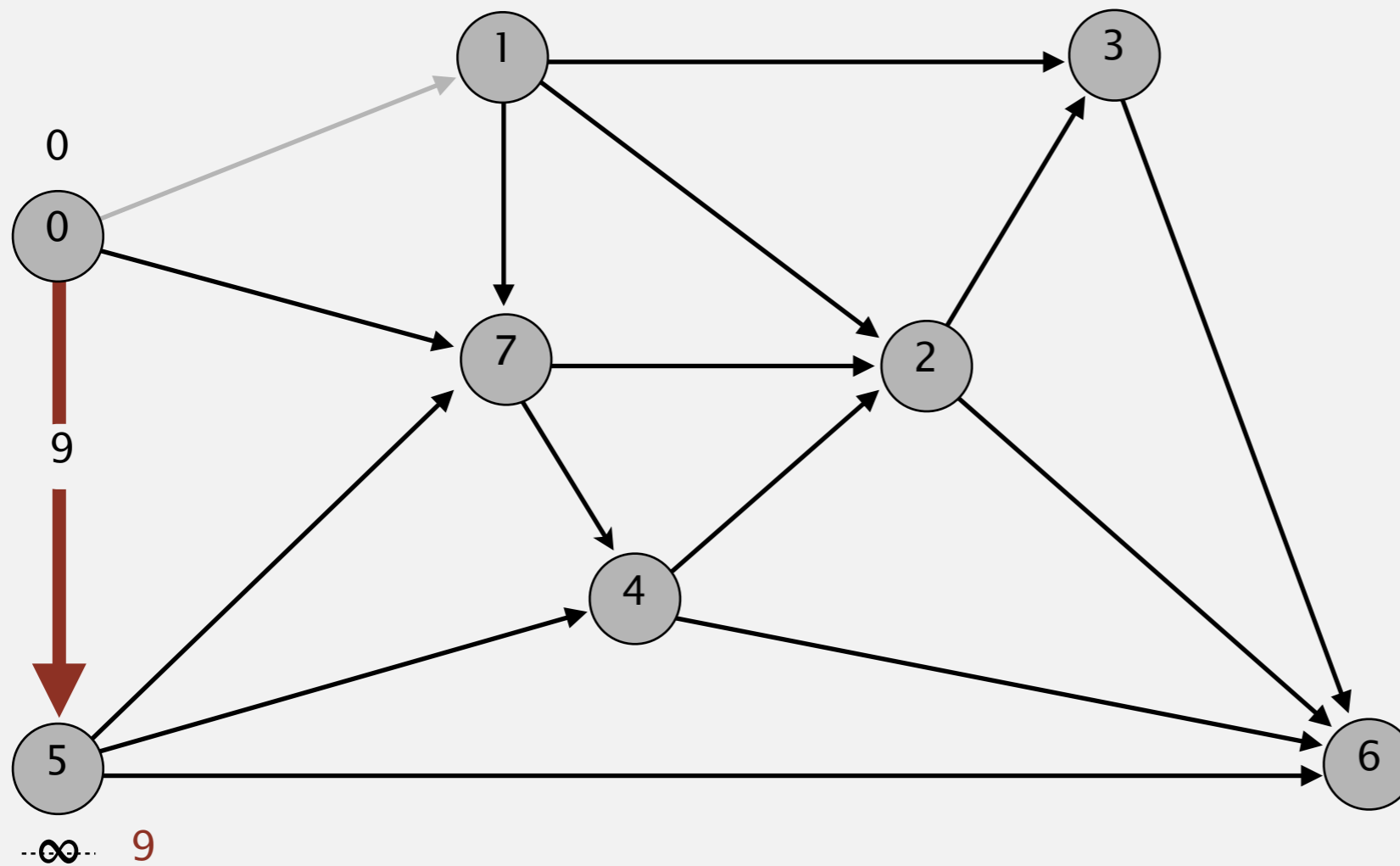
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2		
3		
4		
5	9.0	0→5
6		
7		

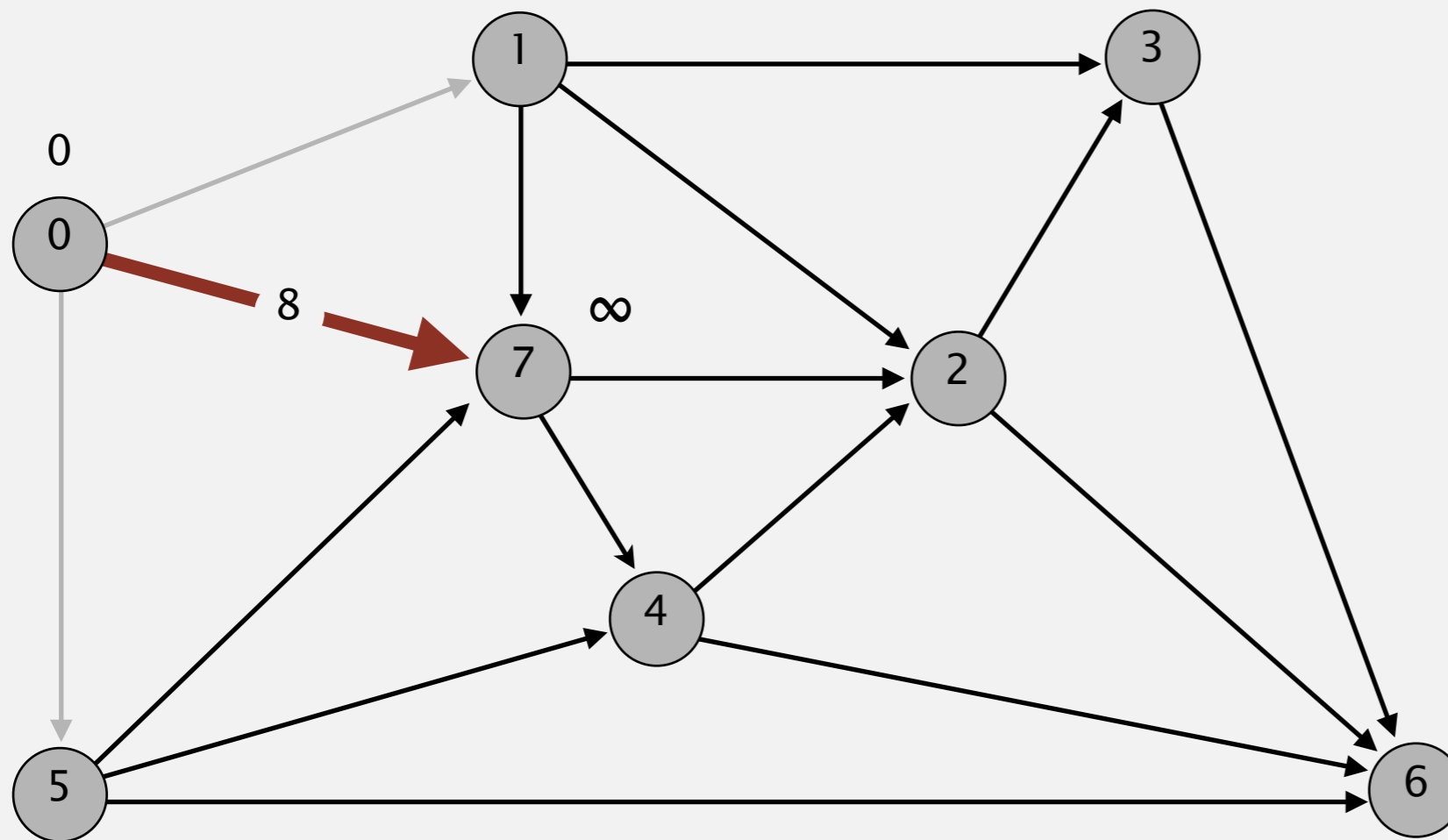
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

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0	0.0	-
1	5.0	0→1
2		
3		
4		
5	9.0	0→5
6		
7		

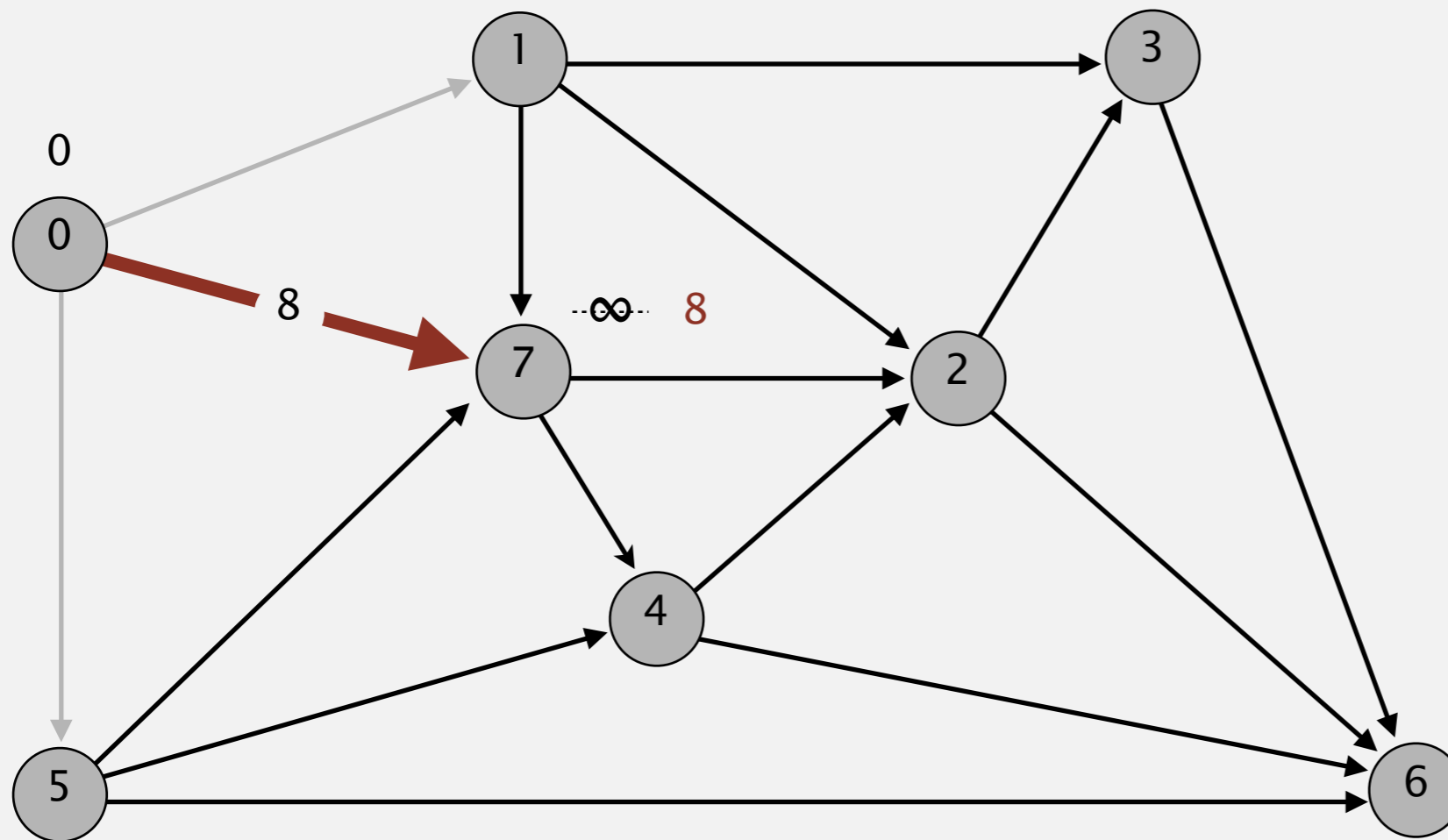
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

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0	0.0	-
1	5.0	0→1
2		
3		
4		
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6		
7	8.0	0→7

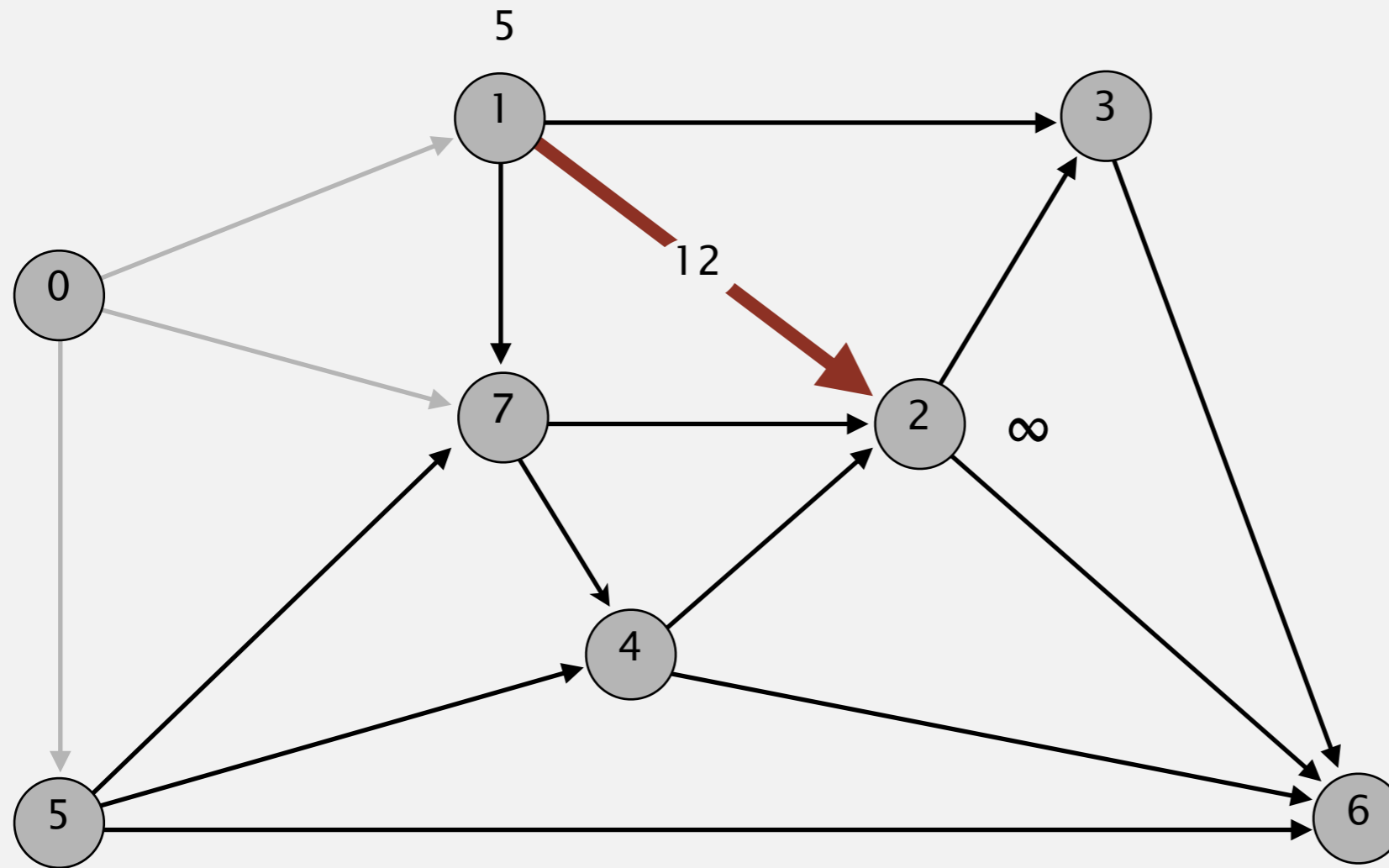
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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0	0.0	-
1	5.0	0→1
2	∞	
3		
4		
5	9.0	0→5
6		
7	8.0	0→7

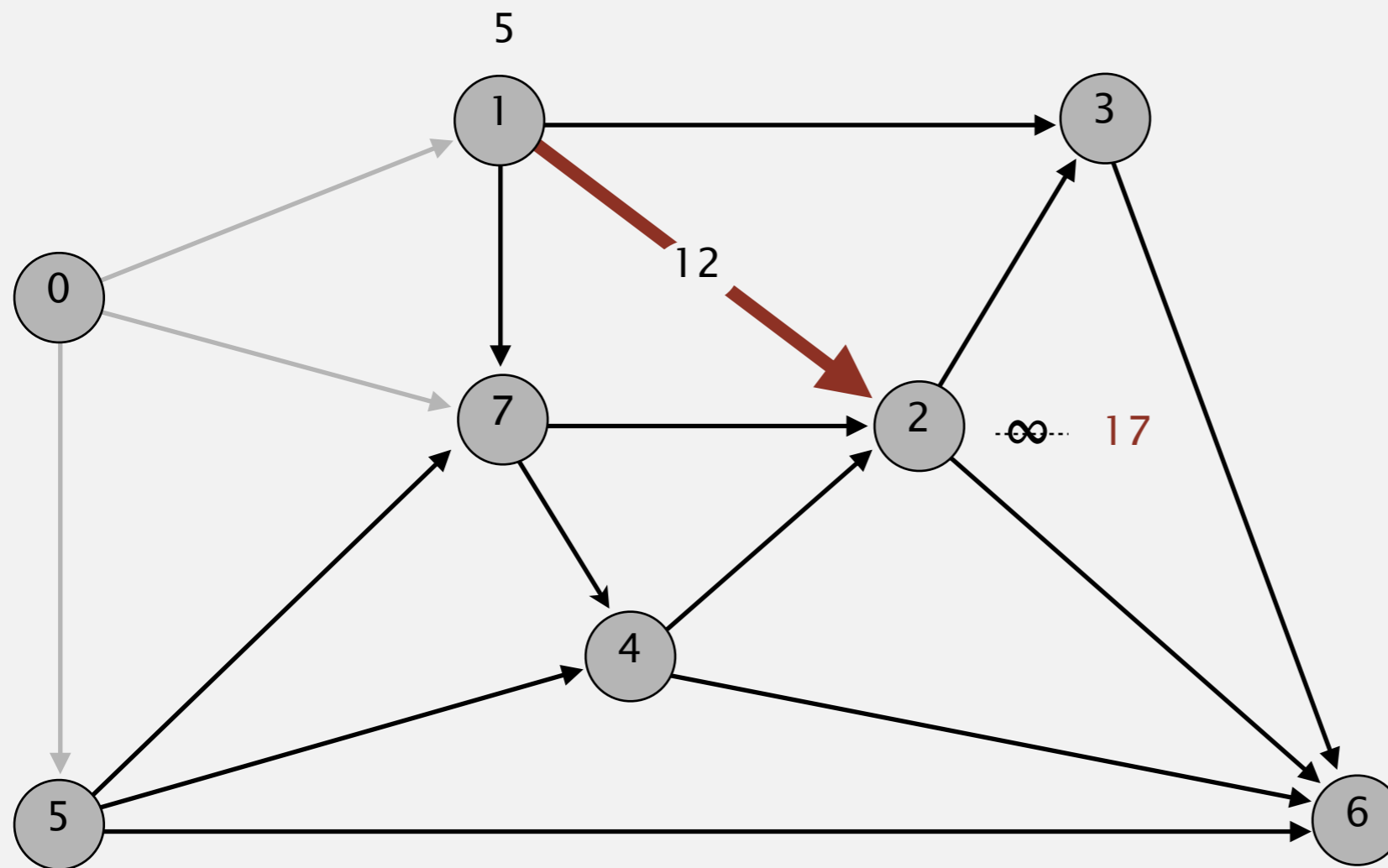
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2	17.0	1→2
3		
4		
5	9.0	0→5
6		
7	8.0	0→7

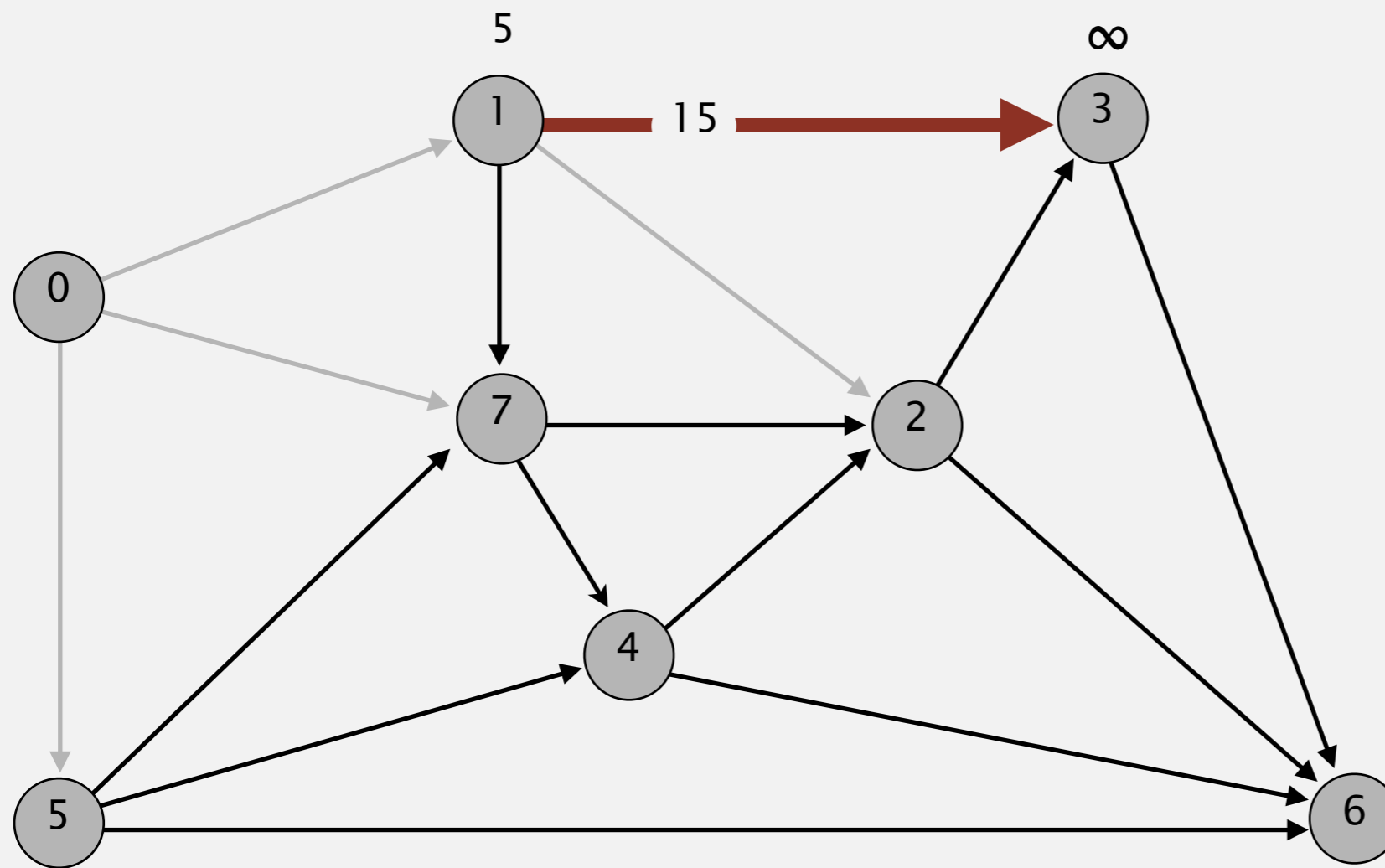
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



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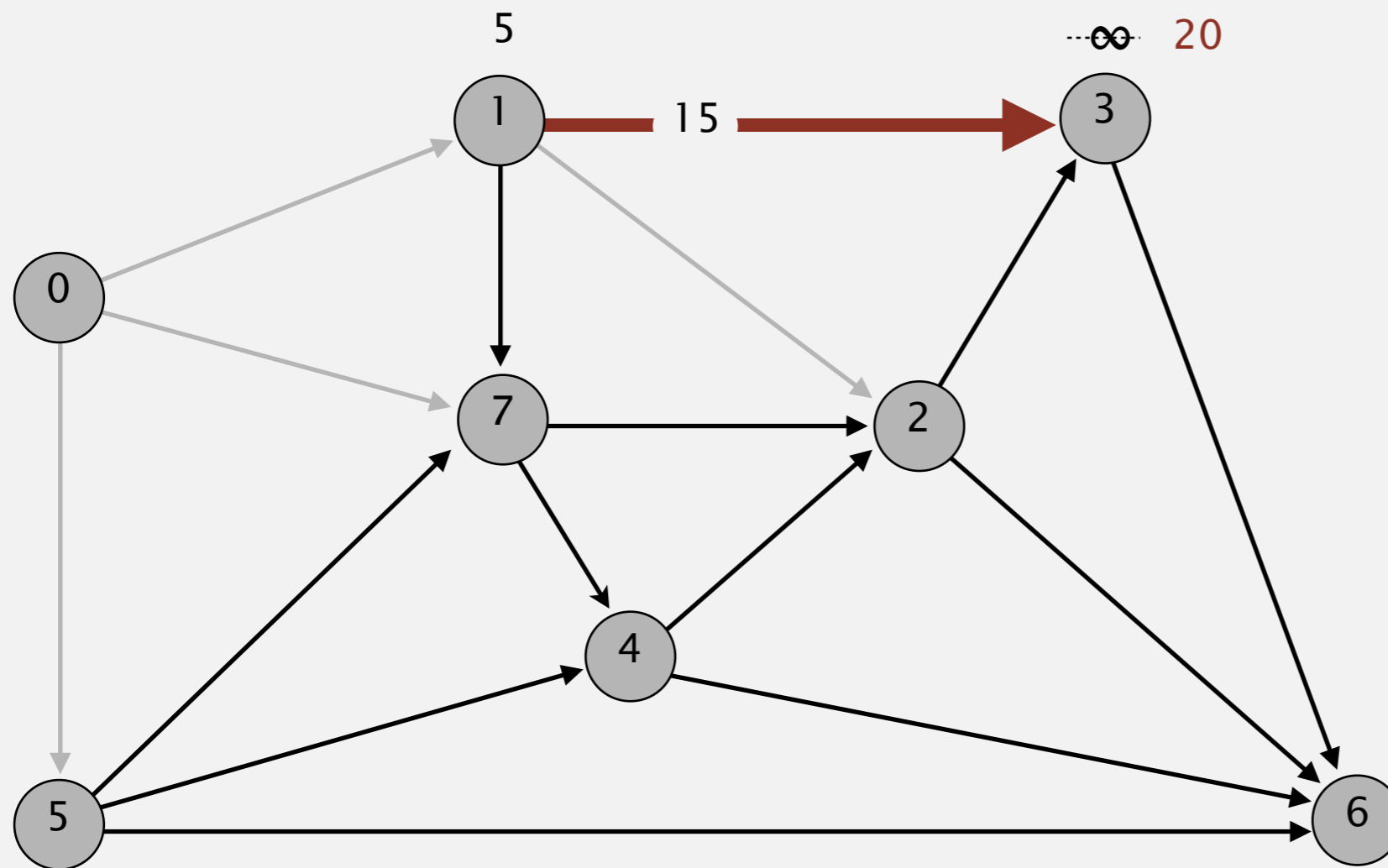
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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0	0.0	-
1	5.0	0→1
2	17.0	1→2
3	20.0	1→3
4		
5	9.0	0→5
6		
7	8.0	0→7

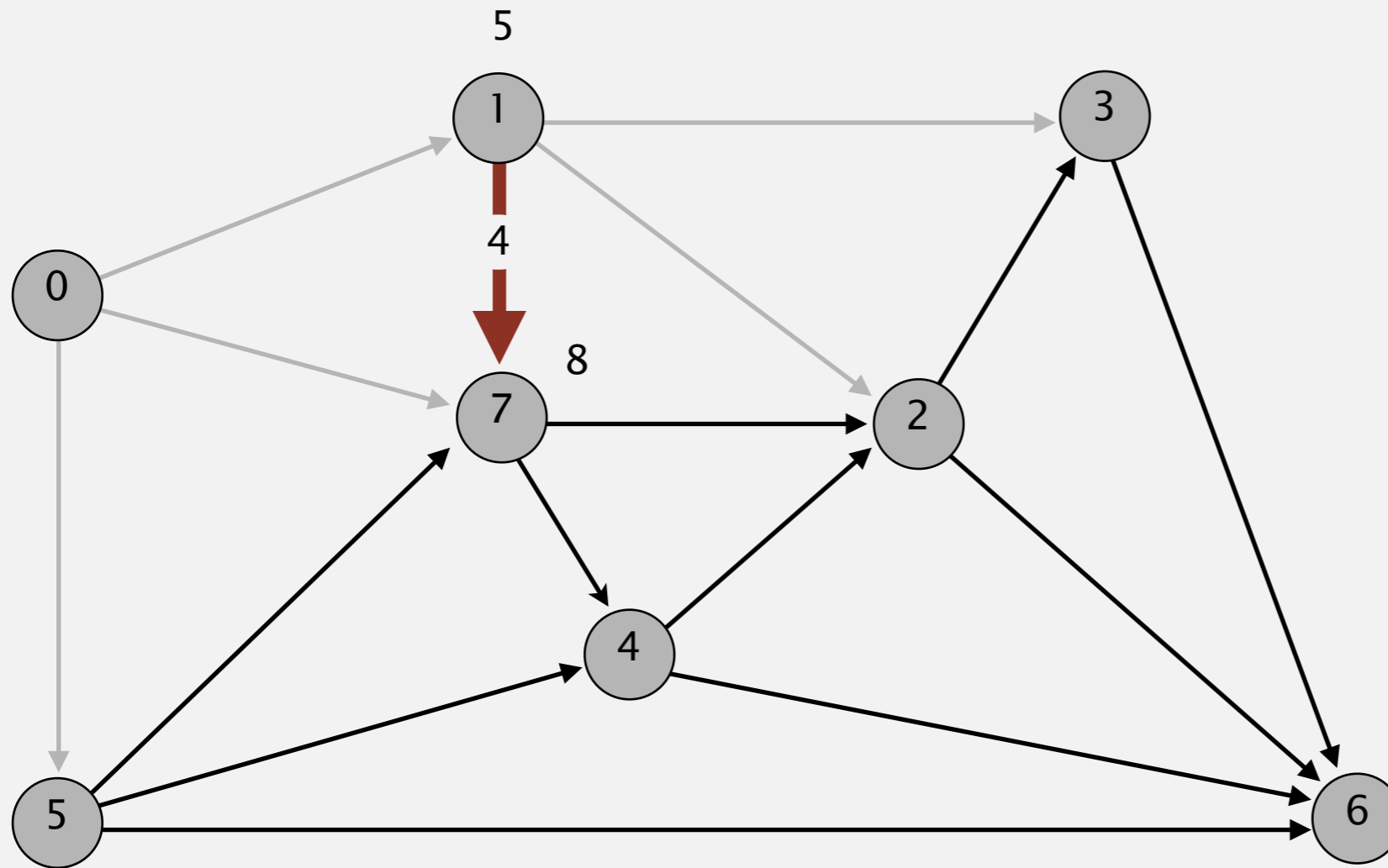
pass 1

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4		
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7	8.0	0→7

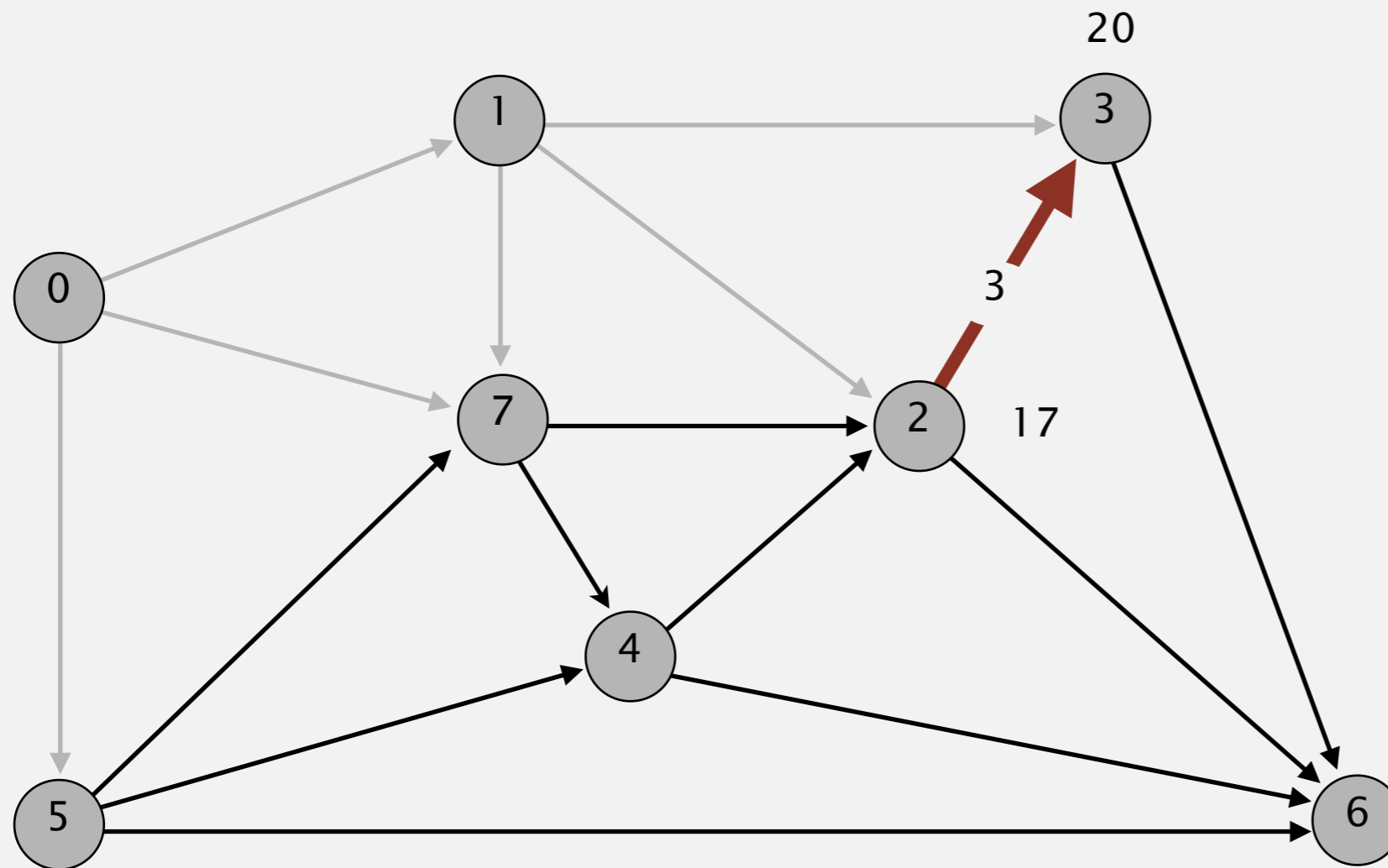
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



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6		
7	8.0	0→7

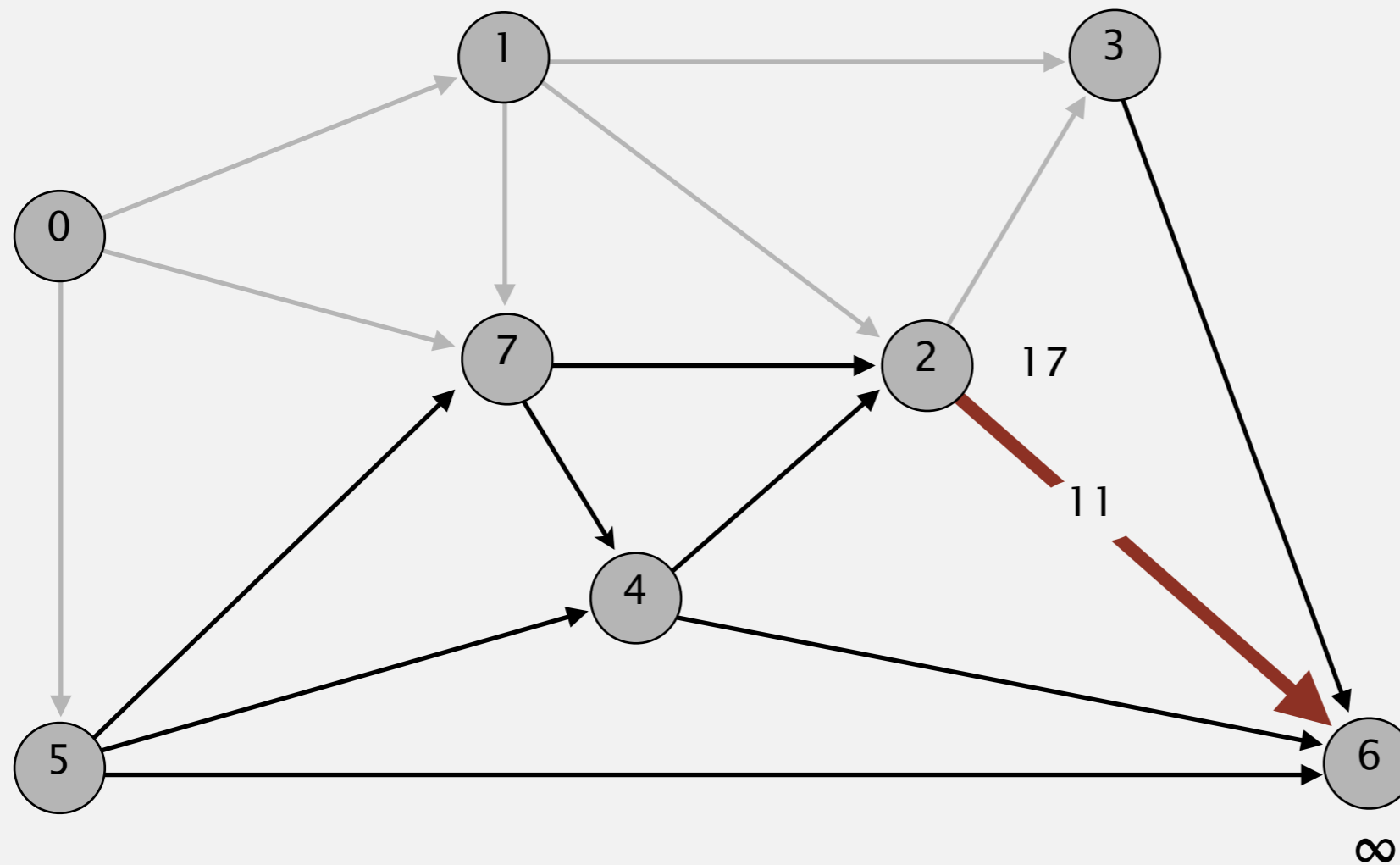
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



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3	20.0	1→3
4		
5	9.0	0→5
6		
7	8.0	0→7

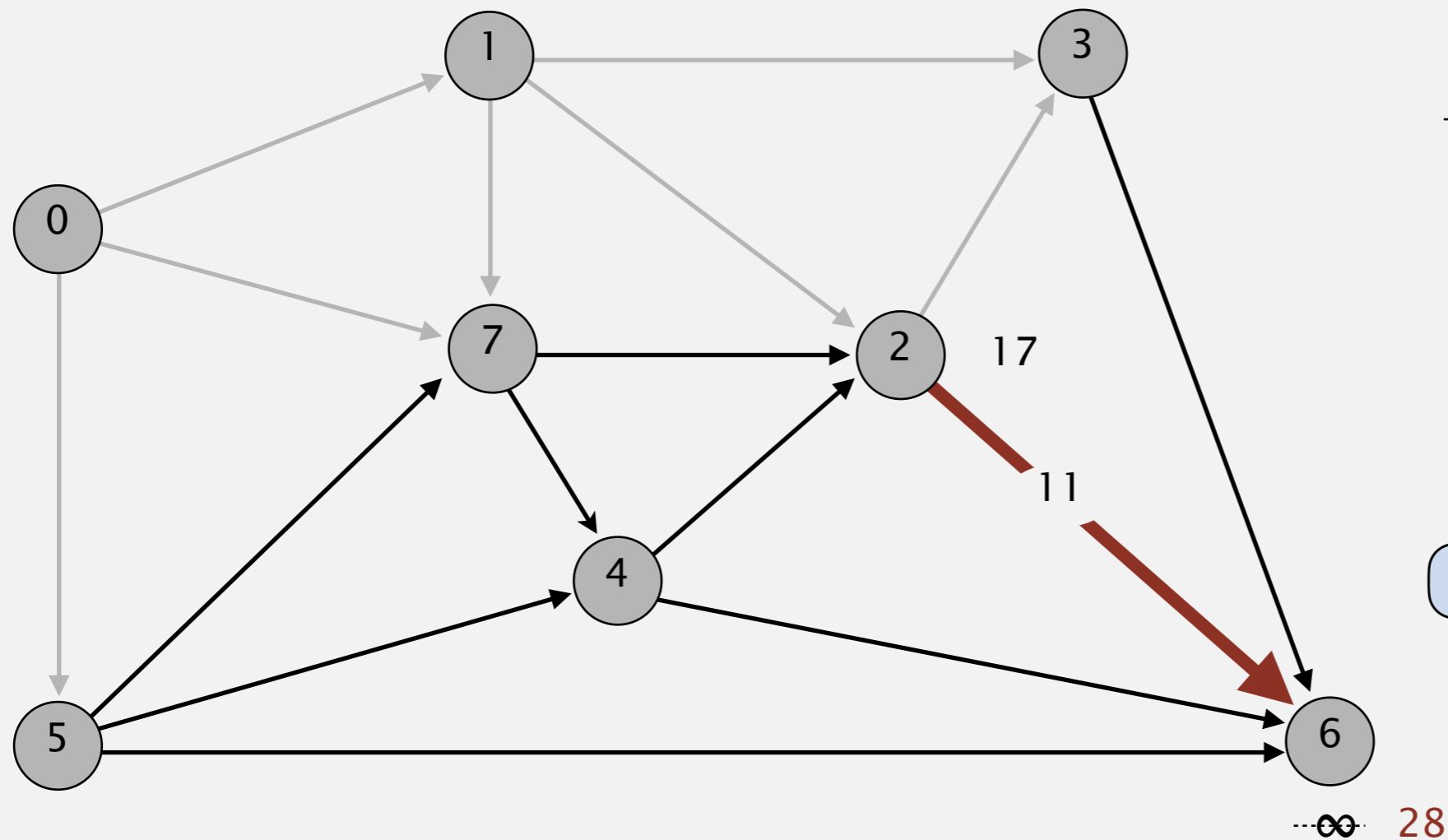
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



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0	0.0	-
1	5.0	0→1
2	17.0	1→2
3	20.0	1→3
4		
5	9.0	0→5
6	28.0	2→6
7	8.0	0→7

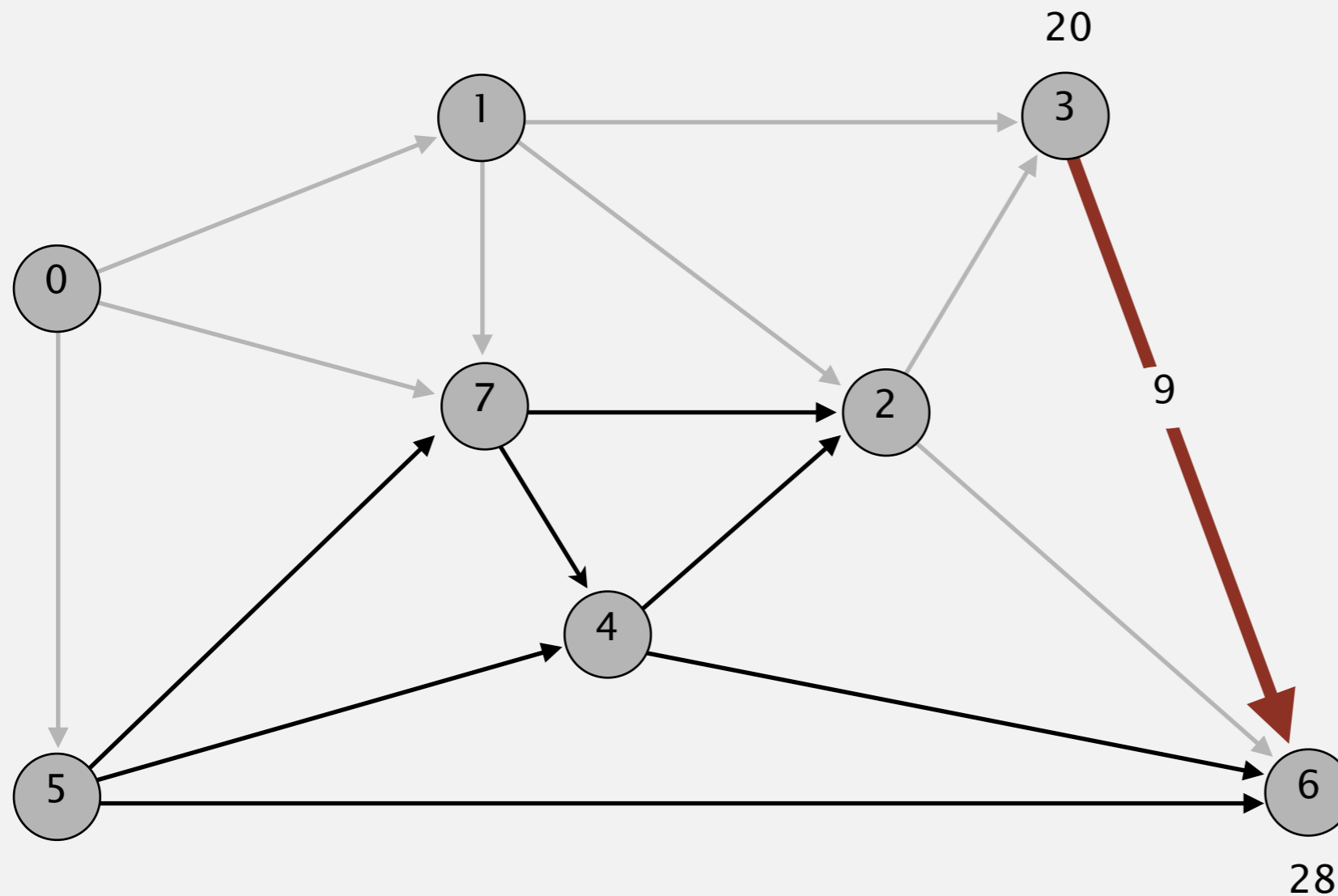
pass 1

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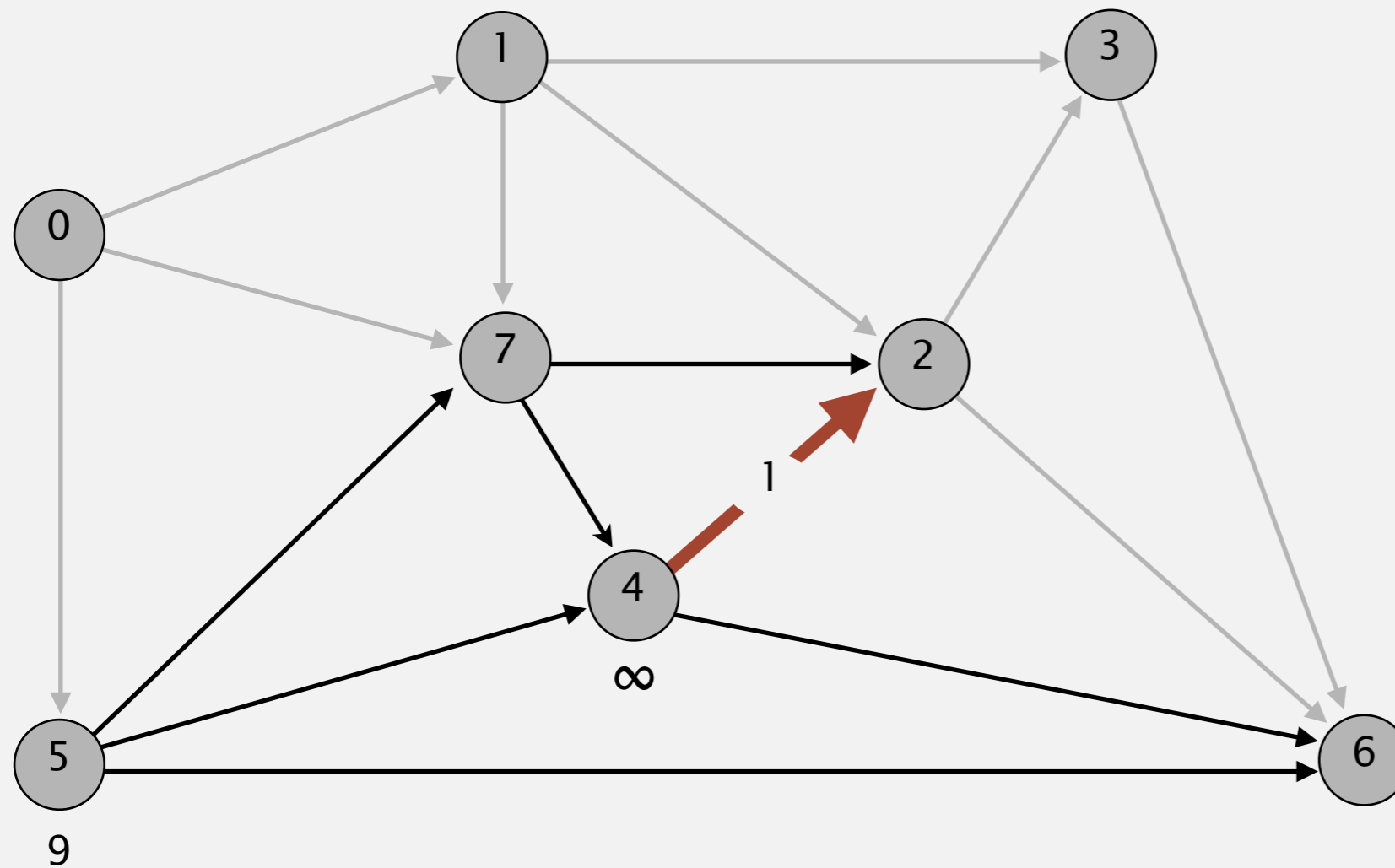
pass 1

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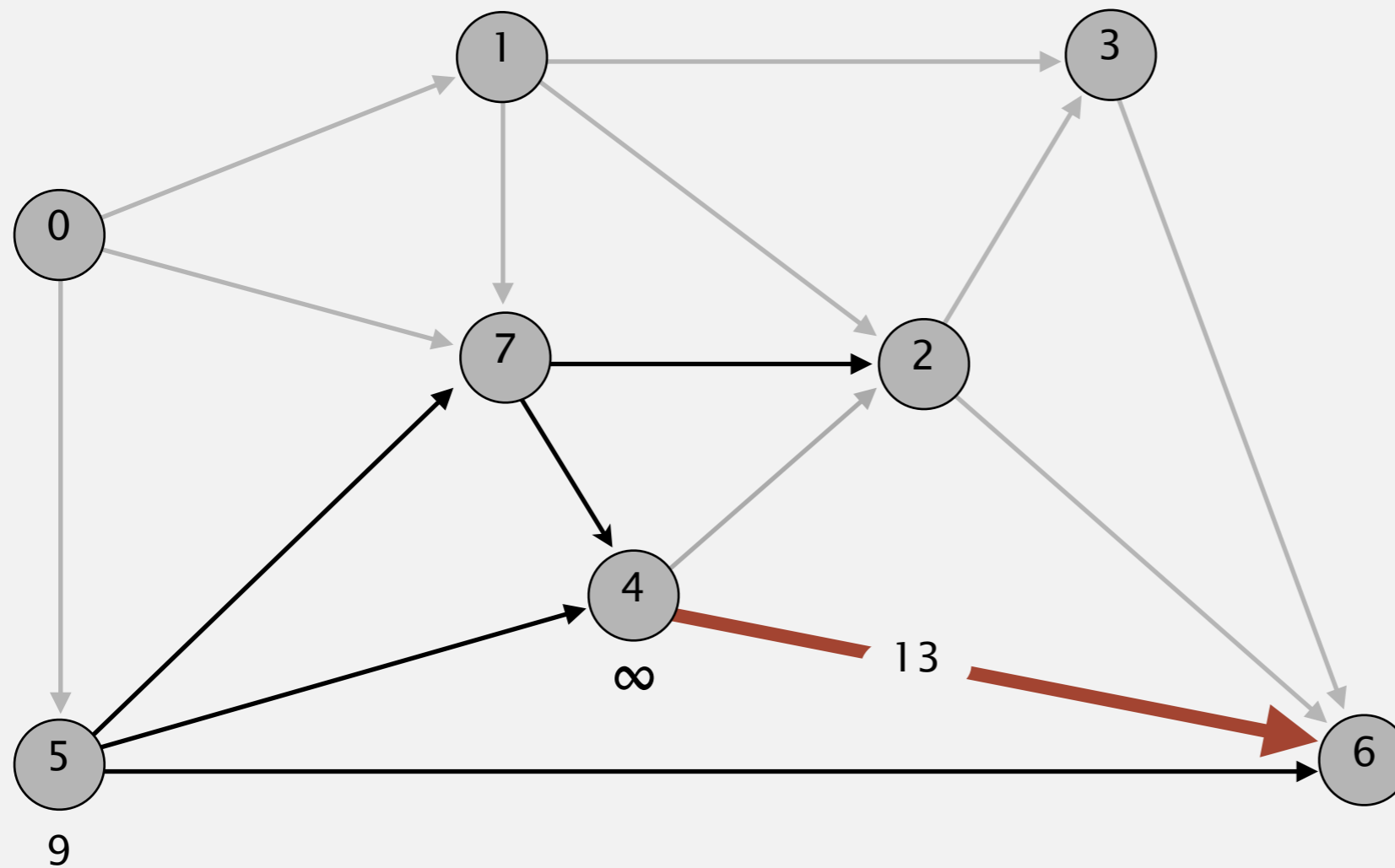
pass 1

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7	8.0	0→7

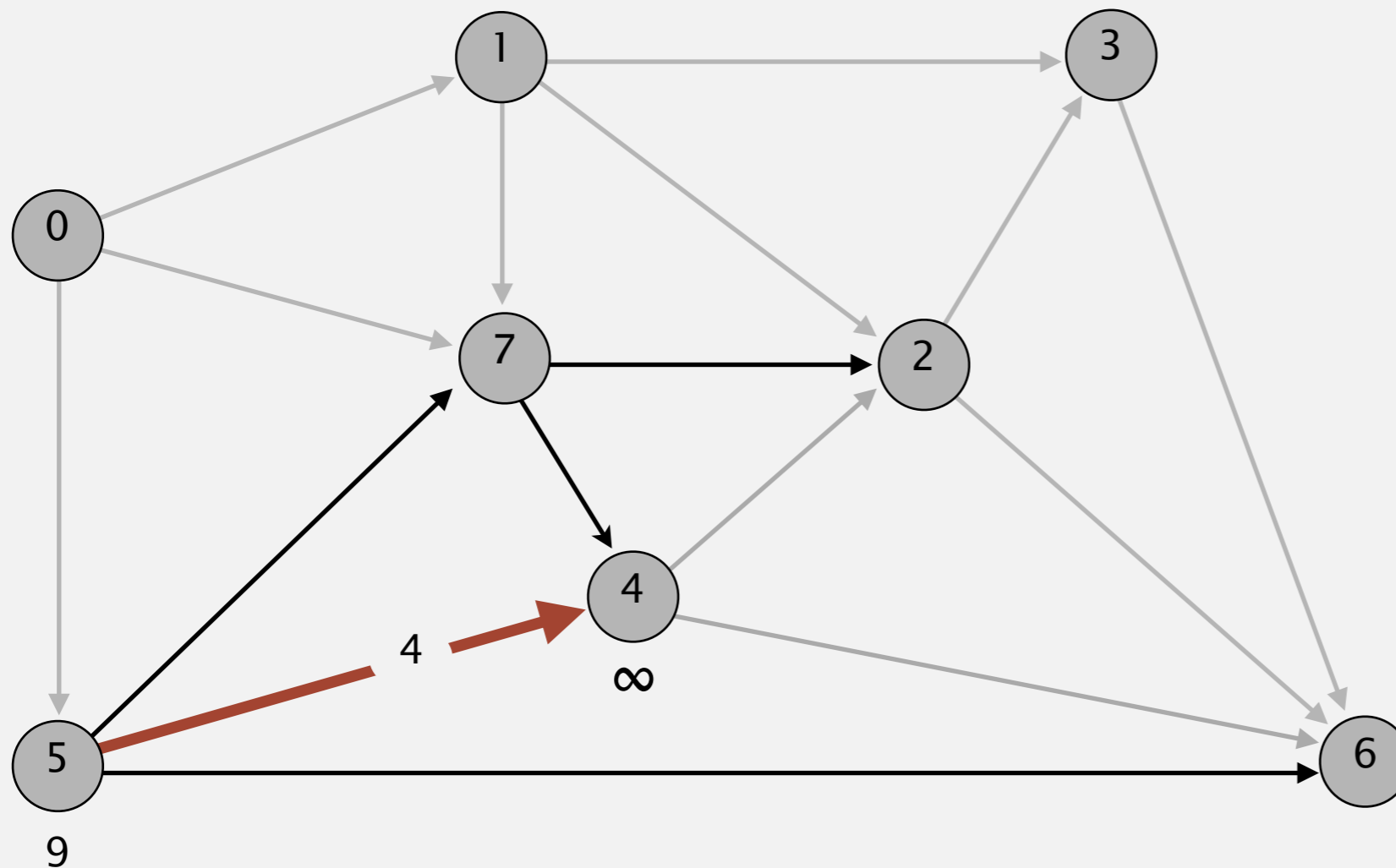
pass 1

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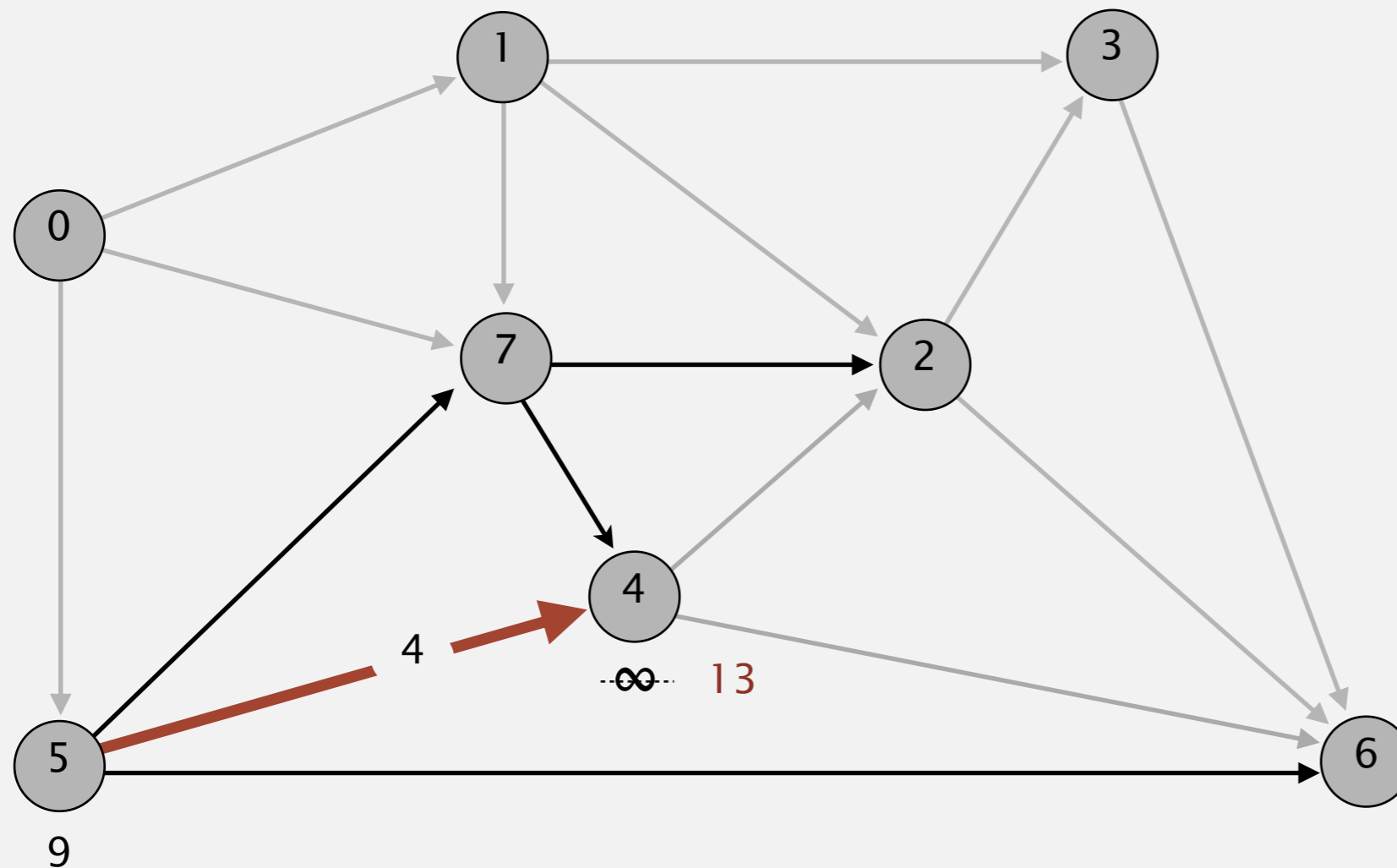
pass 1

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7	8.0	0→7

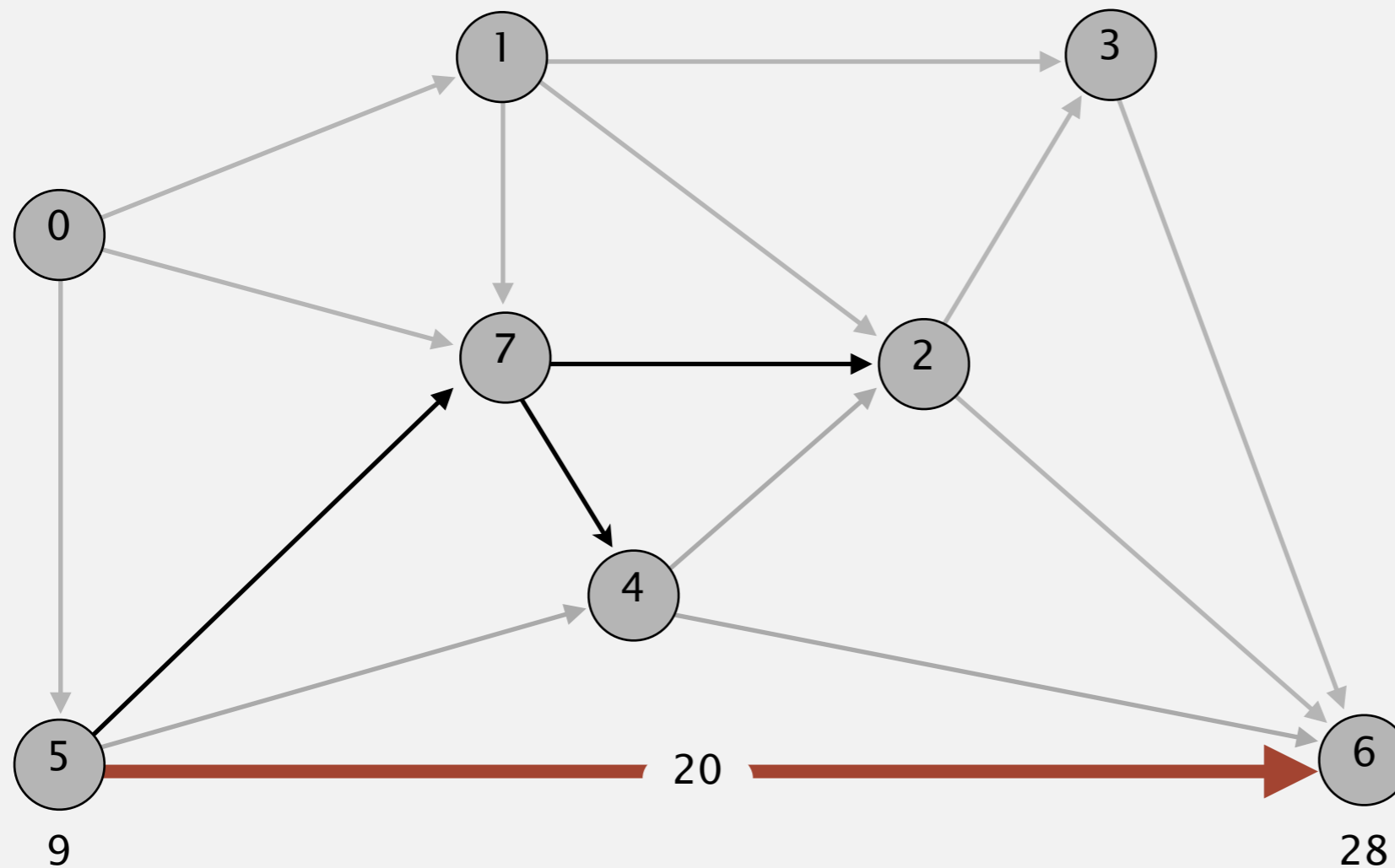
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



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7	8.0	0→7

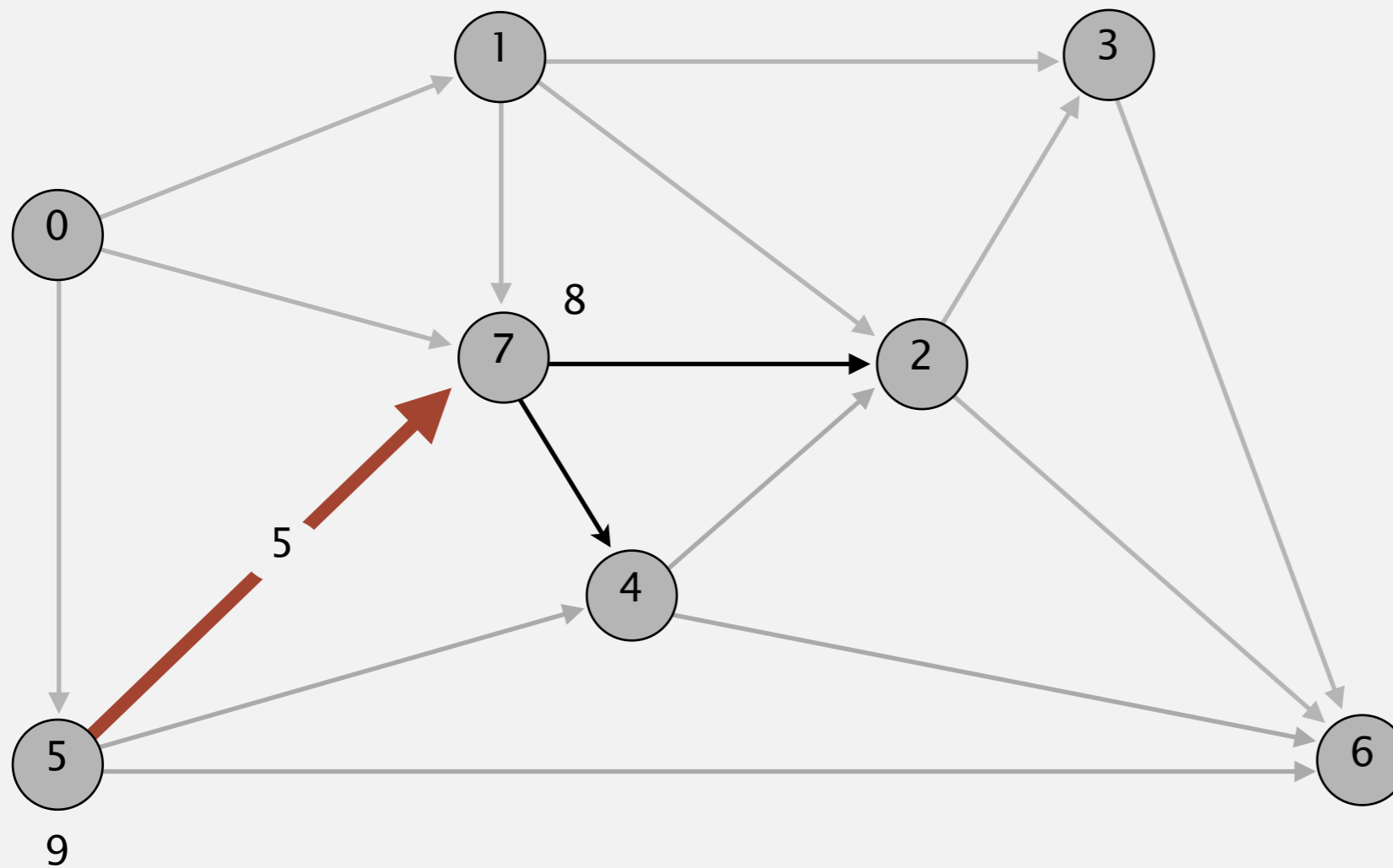
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

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3	20.0	1→3
4	13.0	5→4
5	9.0	0→5
6	28.0	2→6
7	8.0	0→7

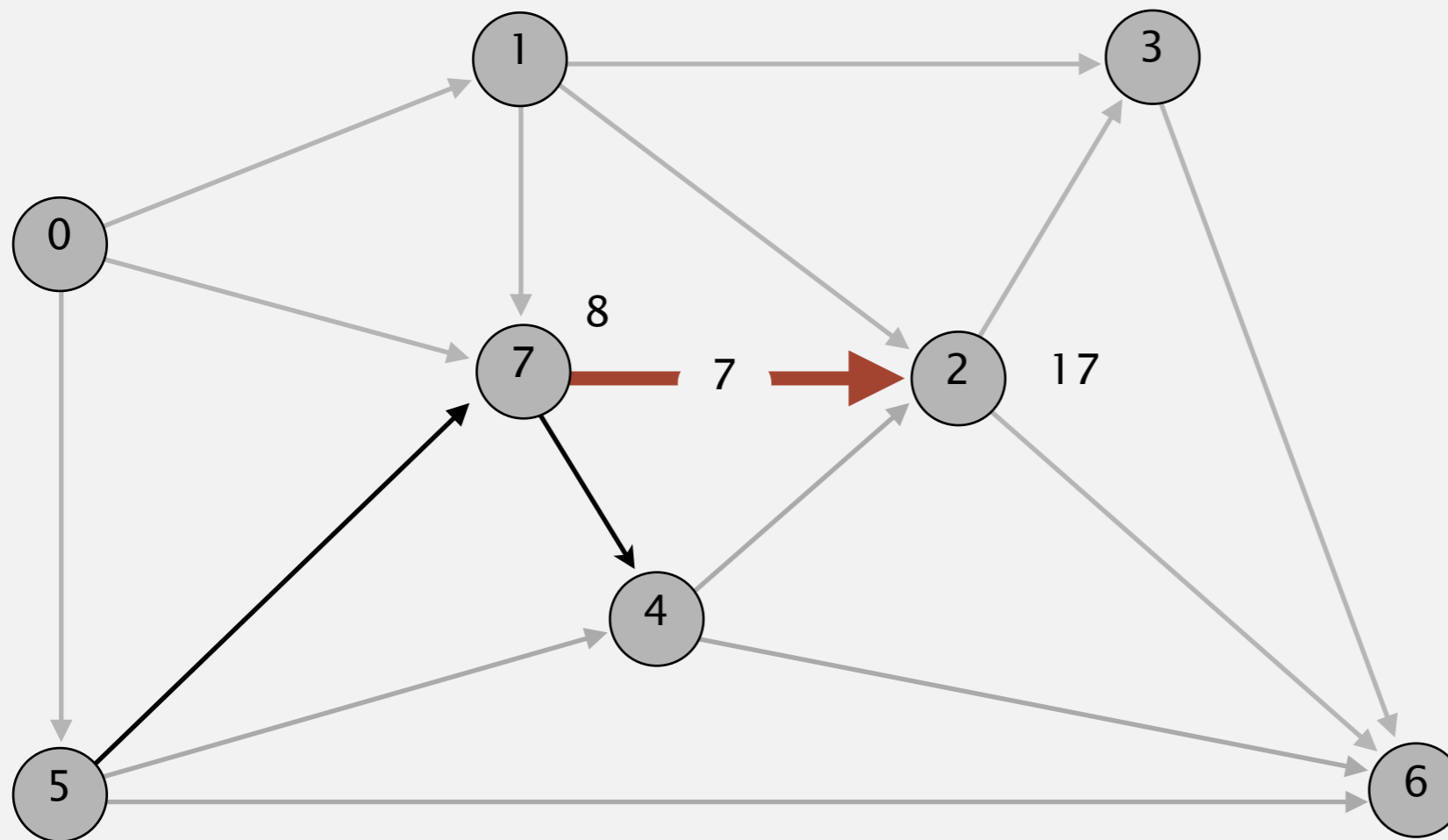
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

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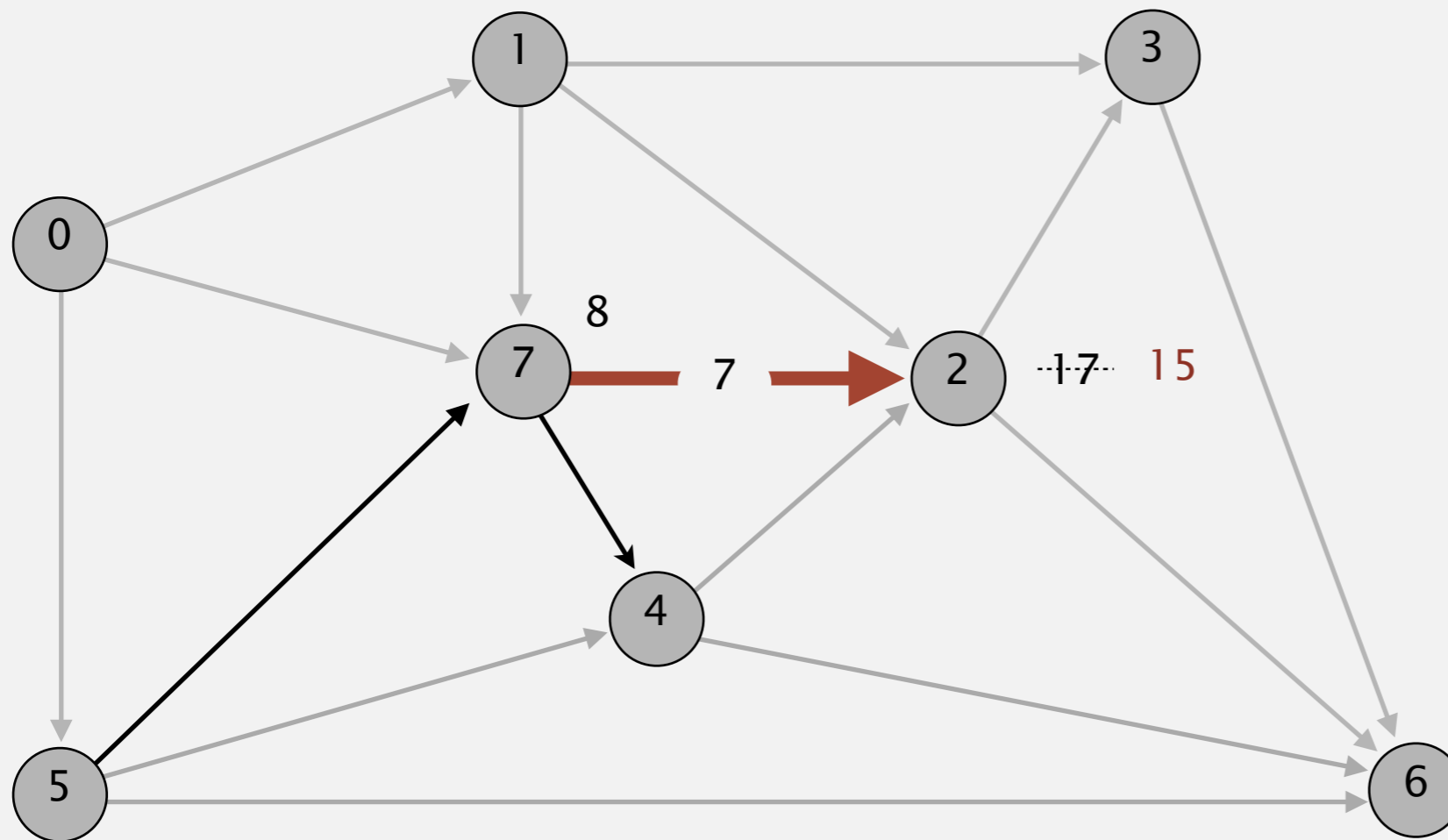
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

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0	0.0	-
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7	8.0	0→7

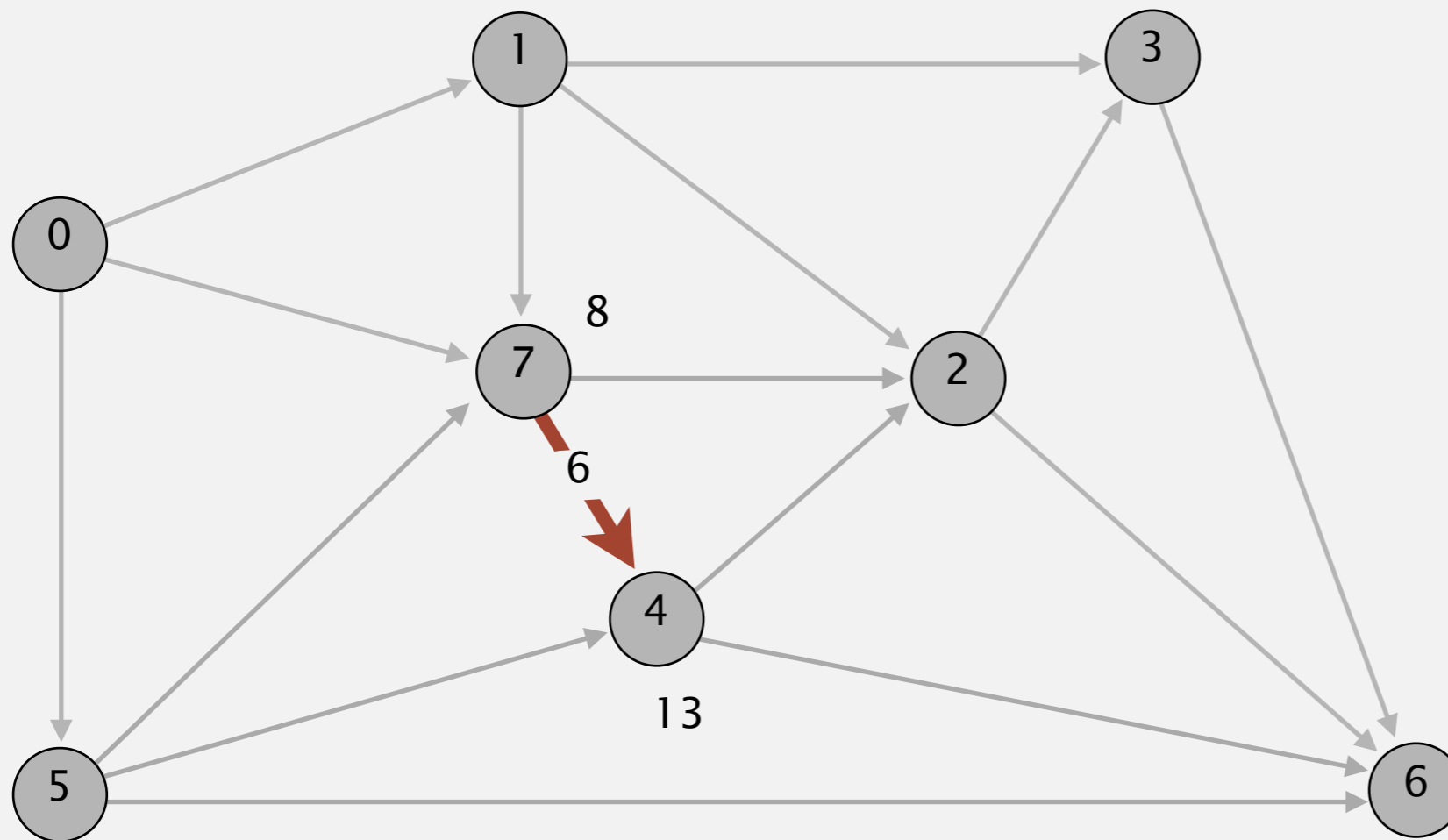
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

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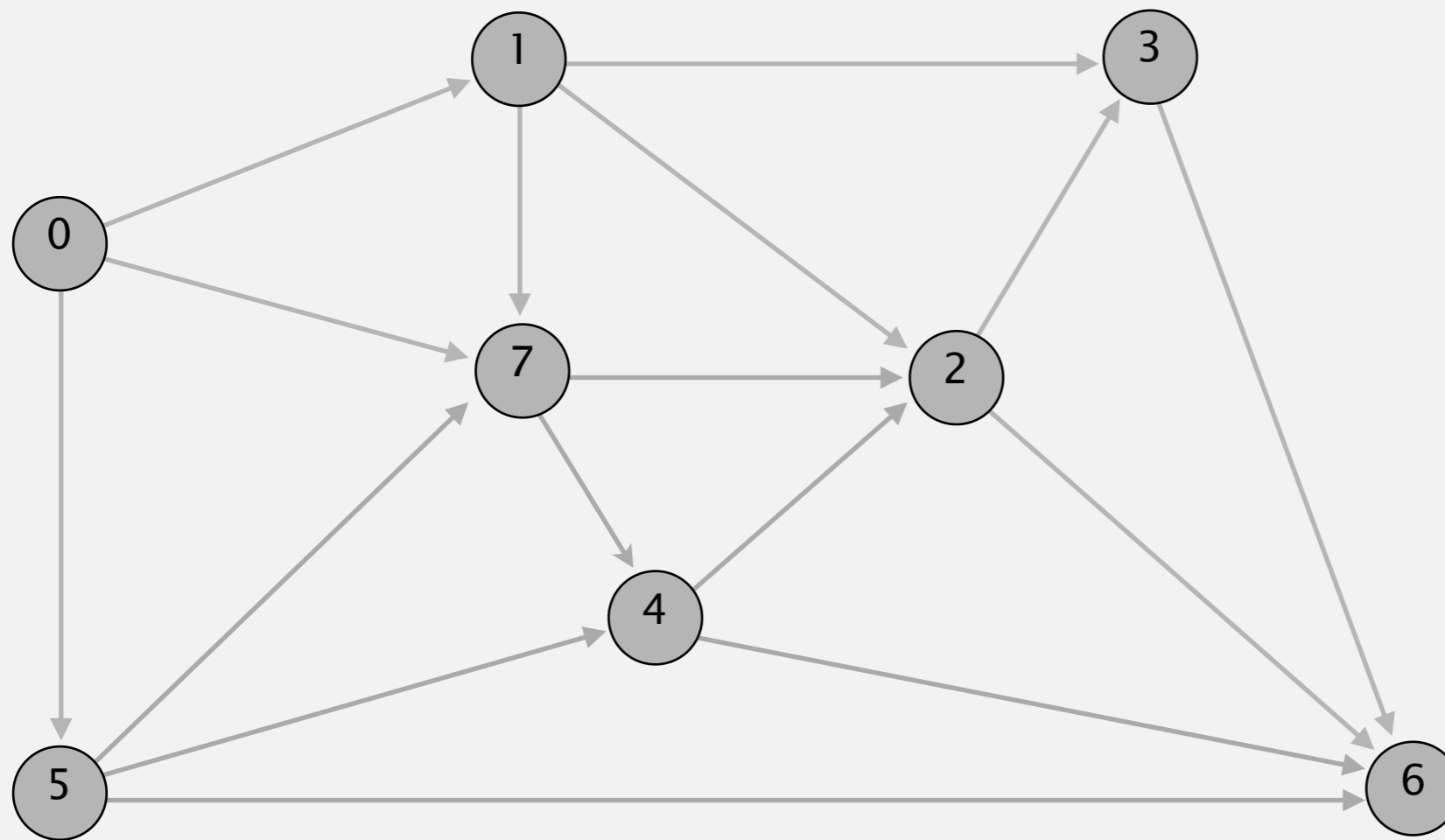
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

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6	28.0	2→6
7	8.0	0→7

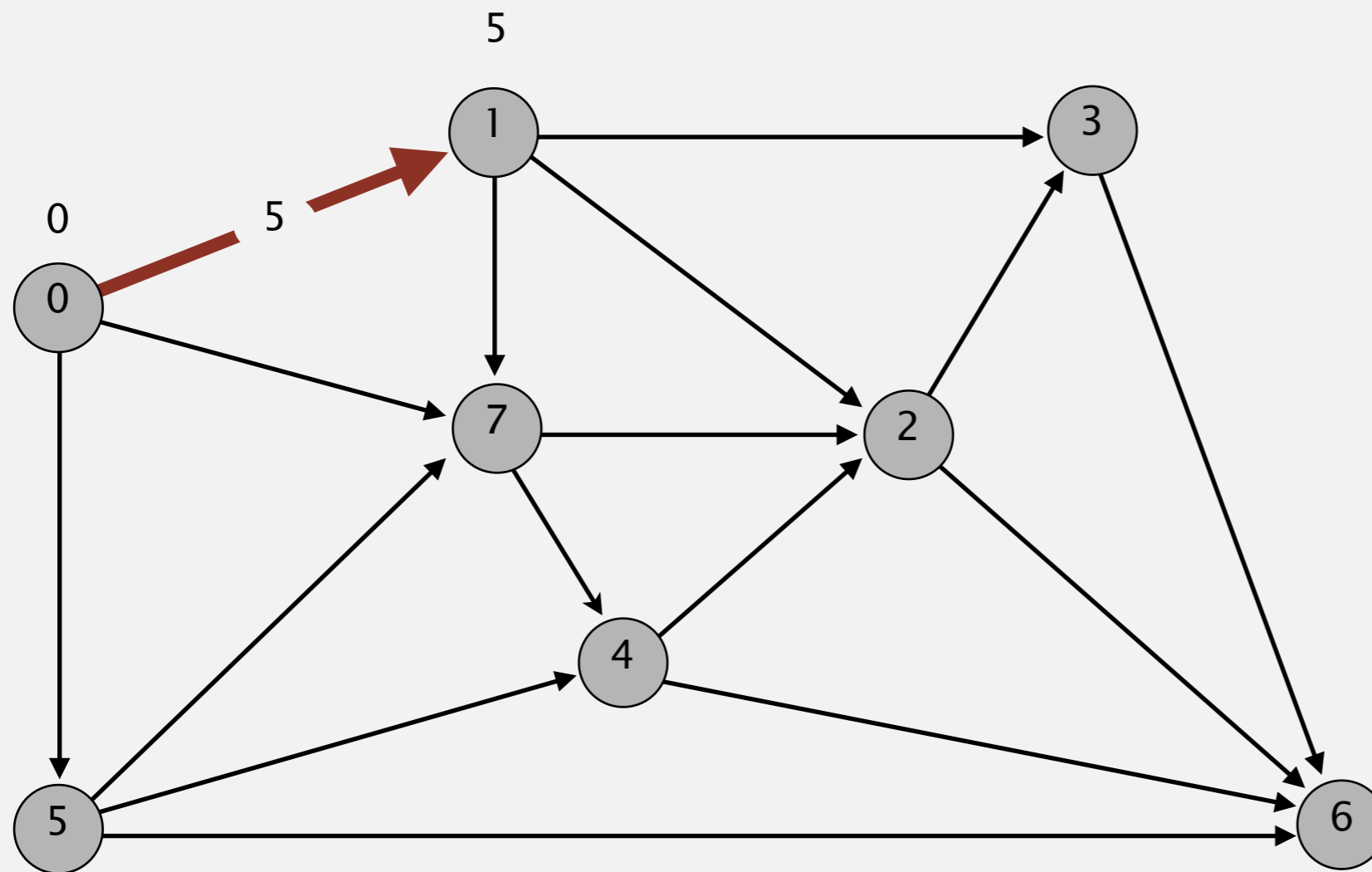
pass 1

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
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4	13.0	5→4
5	9.0	0→5
6	28.0	2→6
7	8.0	0→7

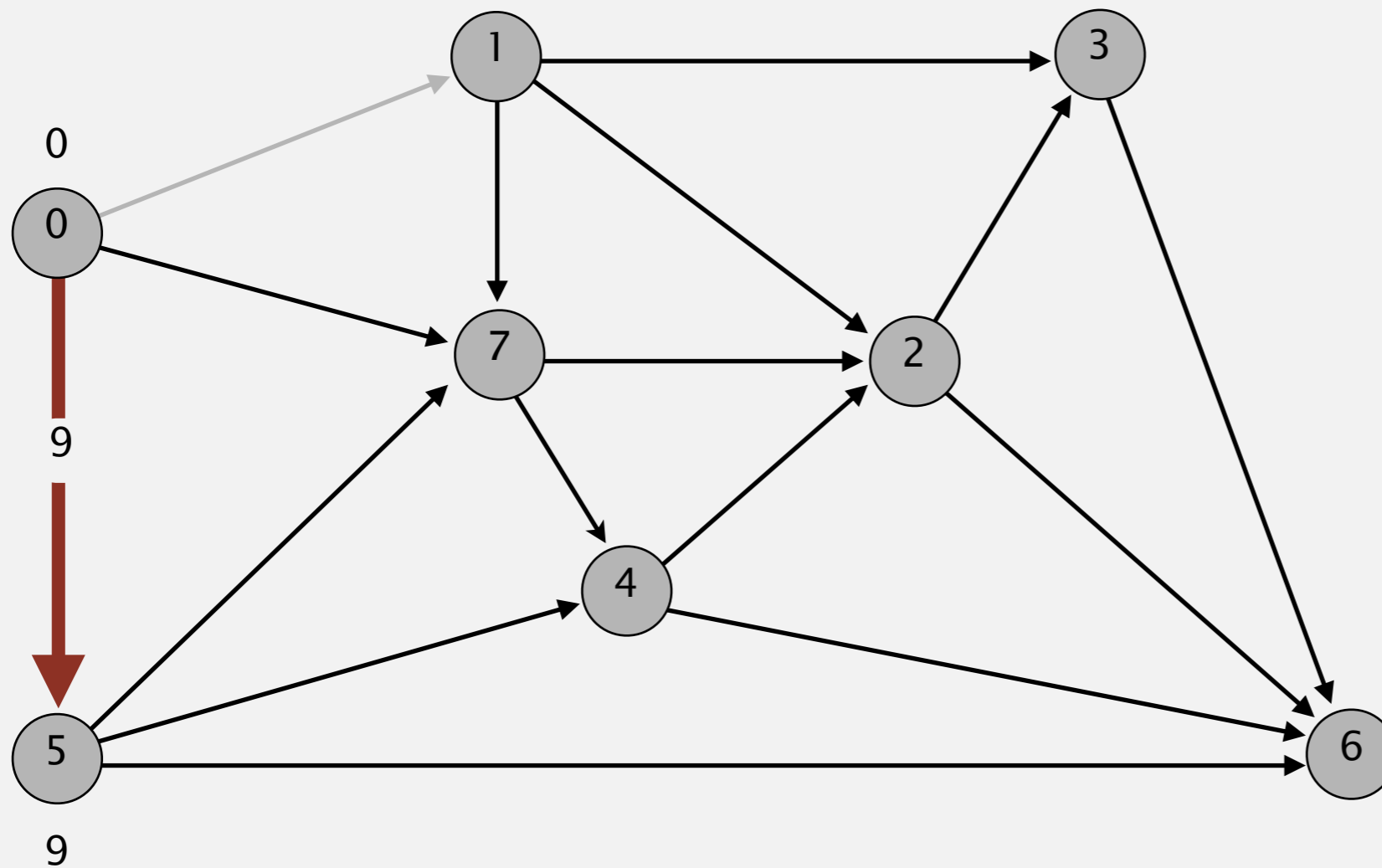
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2	15.0	7→2
3	20.0	1→3
4	13.0	5→4
5	9.0	0→5
6	28.0	2→6
7	8.0	0→7

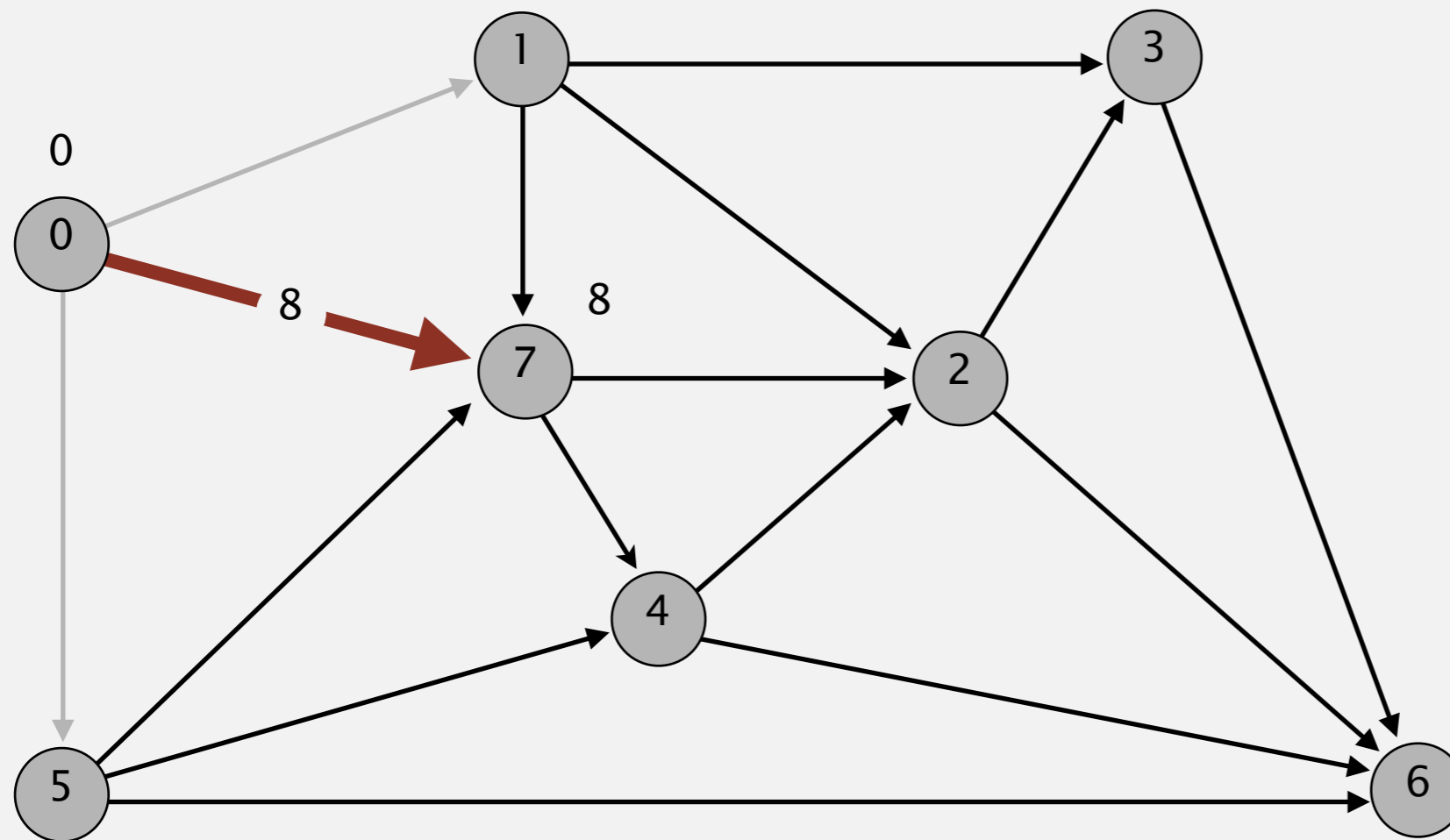
pass 2

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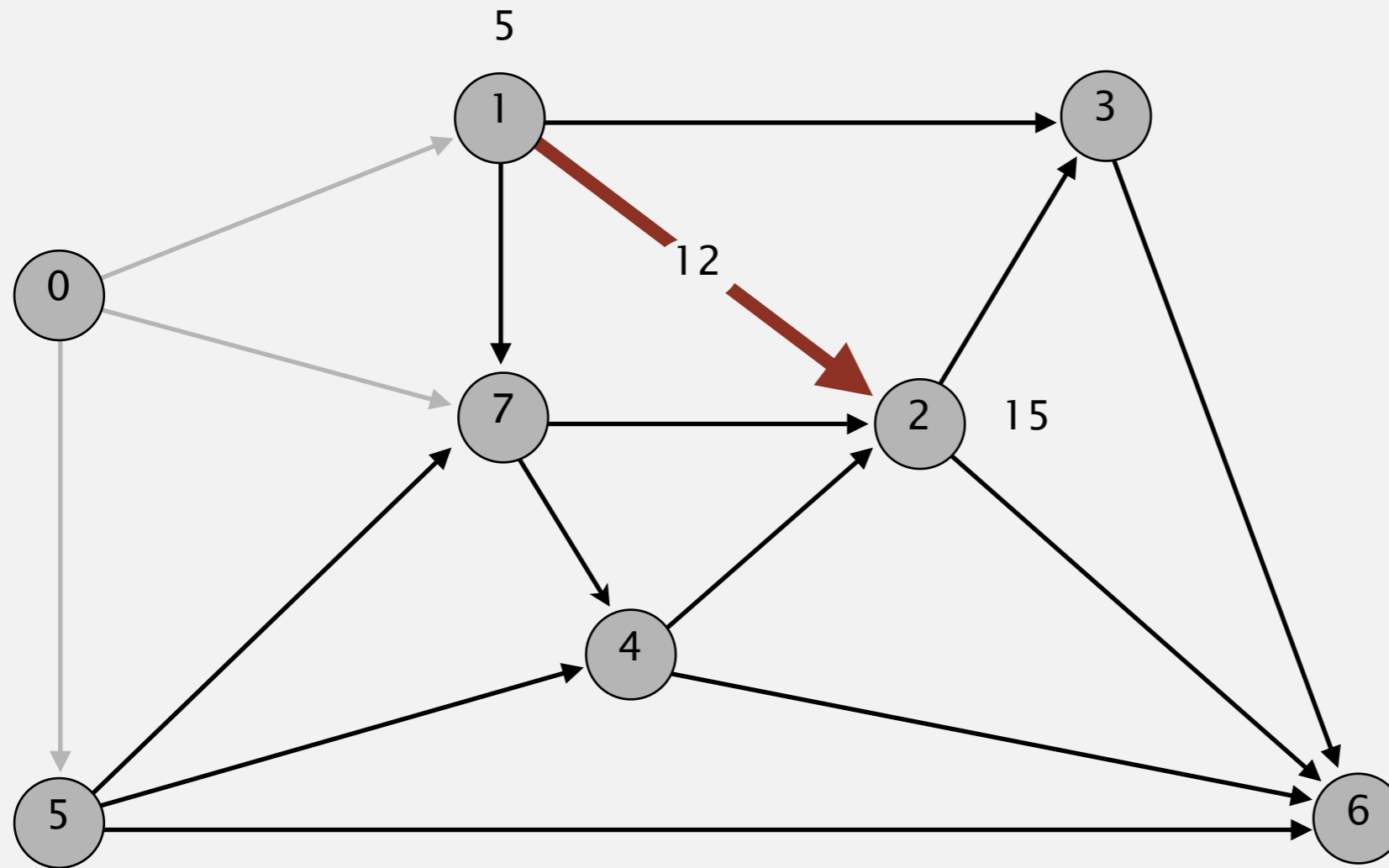
pass 2

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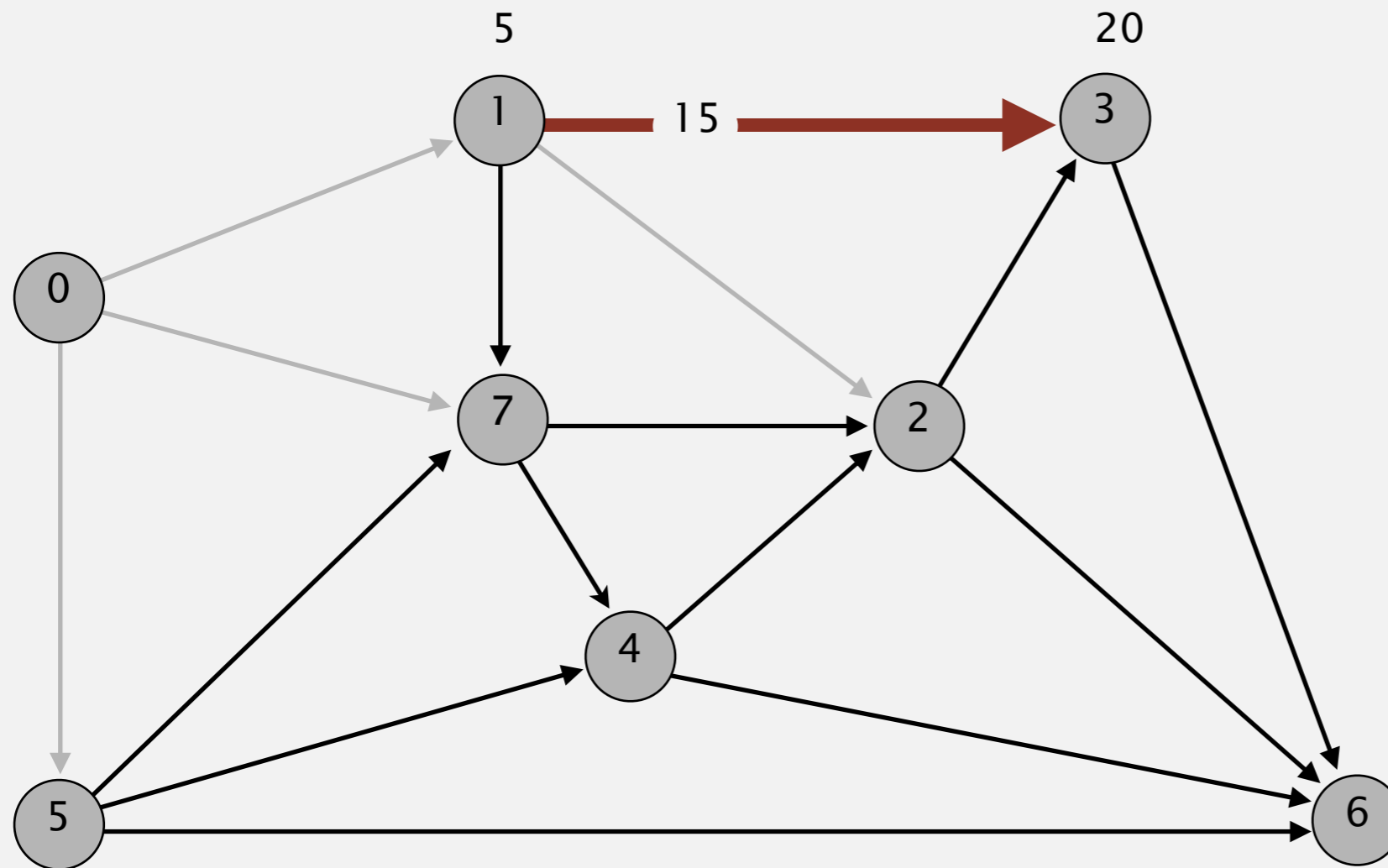
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



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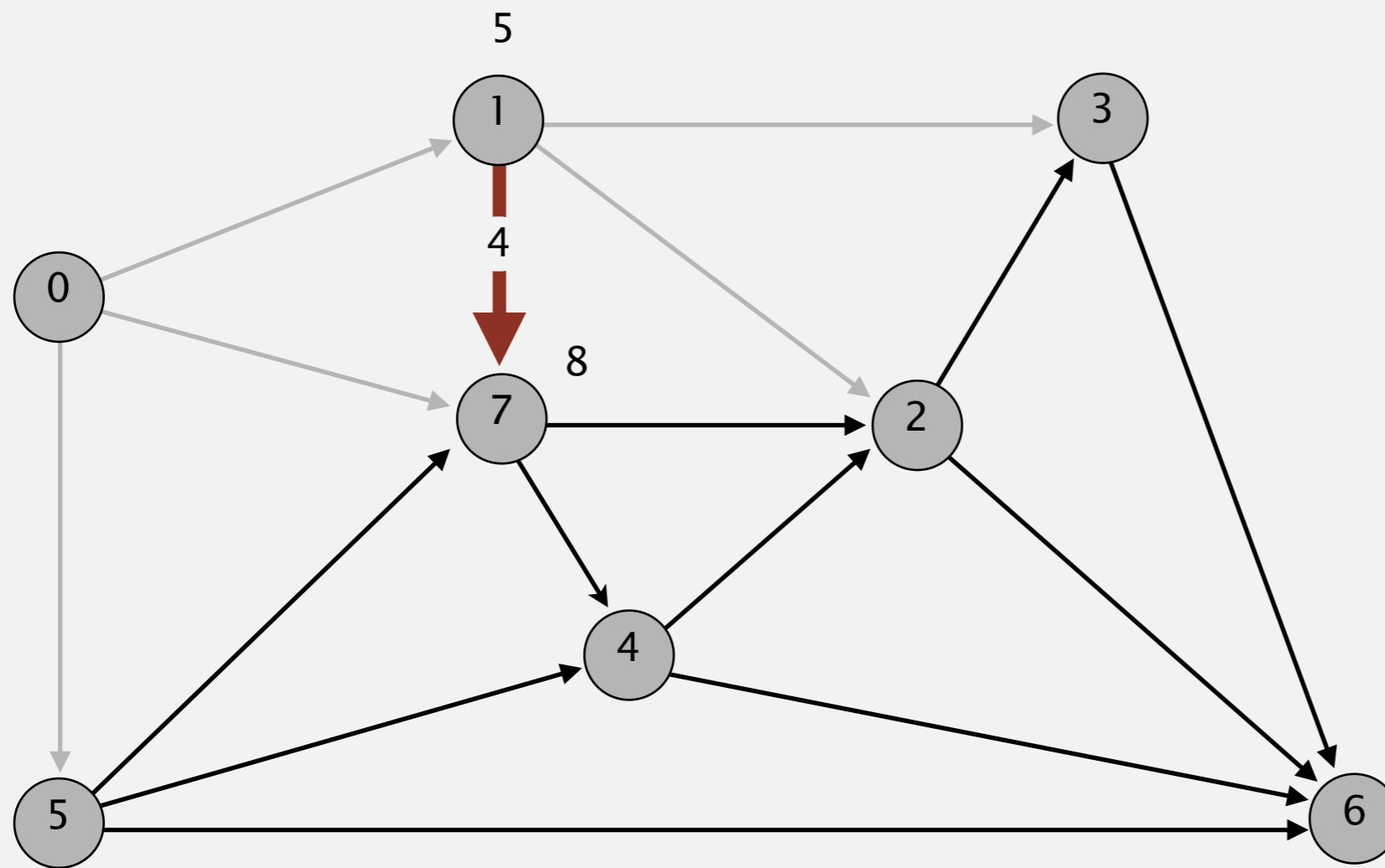
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



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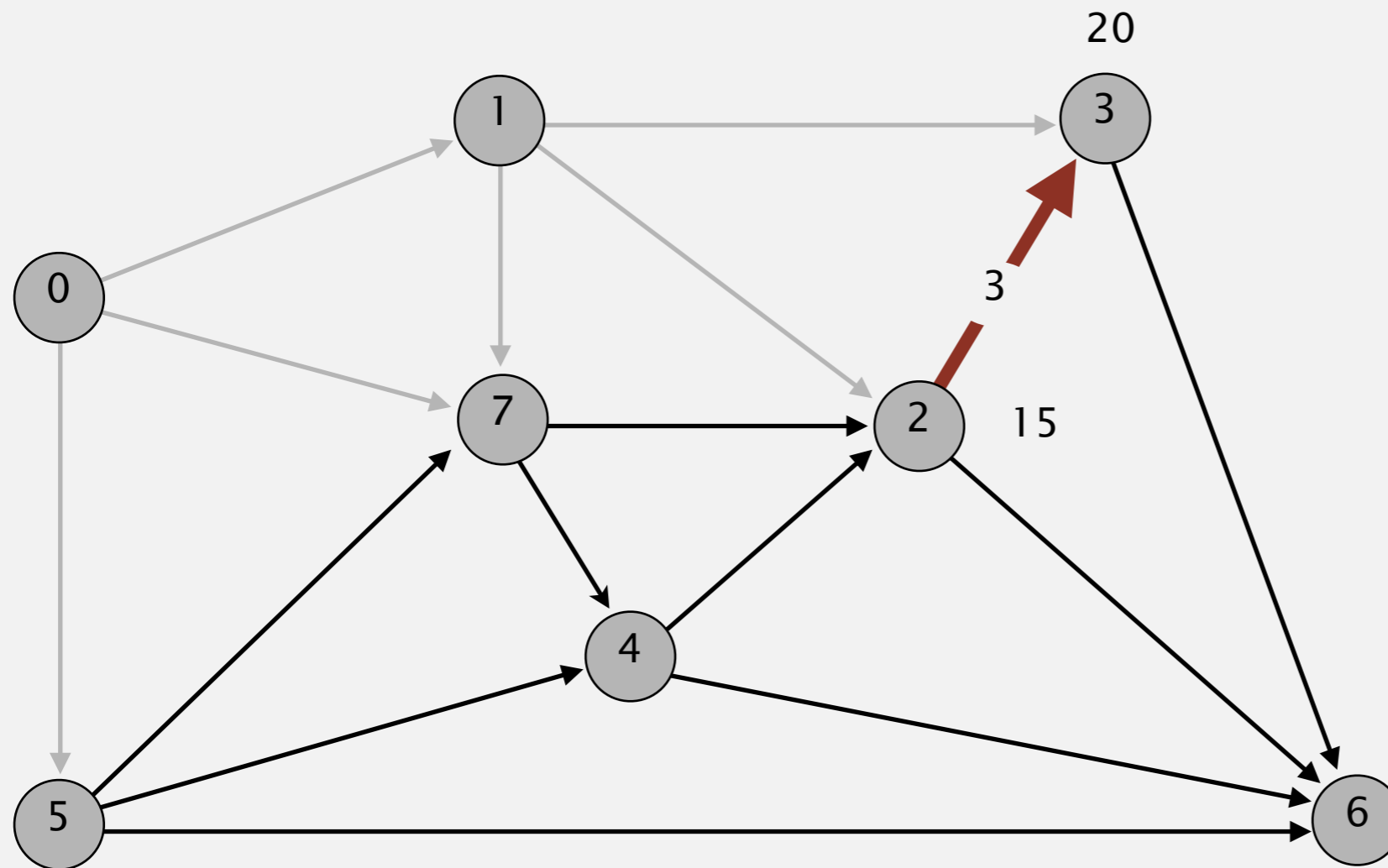
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2	15.0	7→2
3	20.0	1→3
4	13.0	5→4
5	9.0	0→5
6	28.0	2→6
7	8.0	0→7

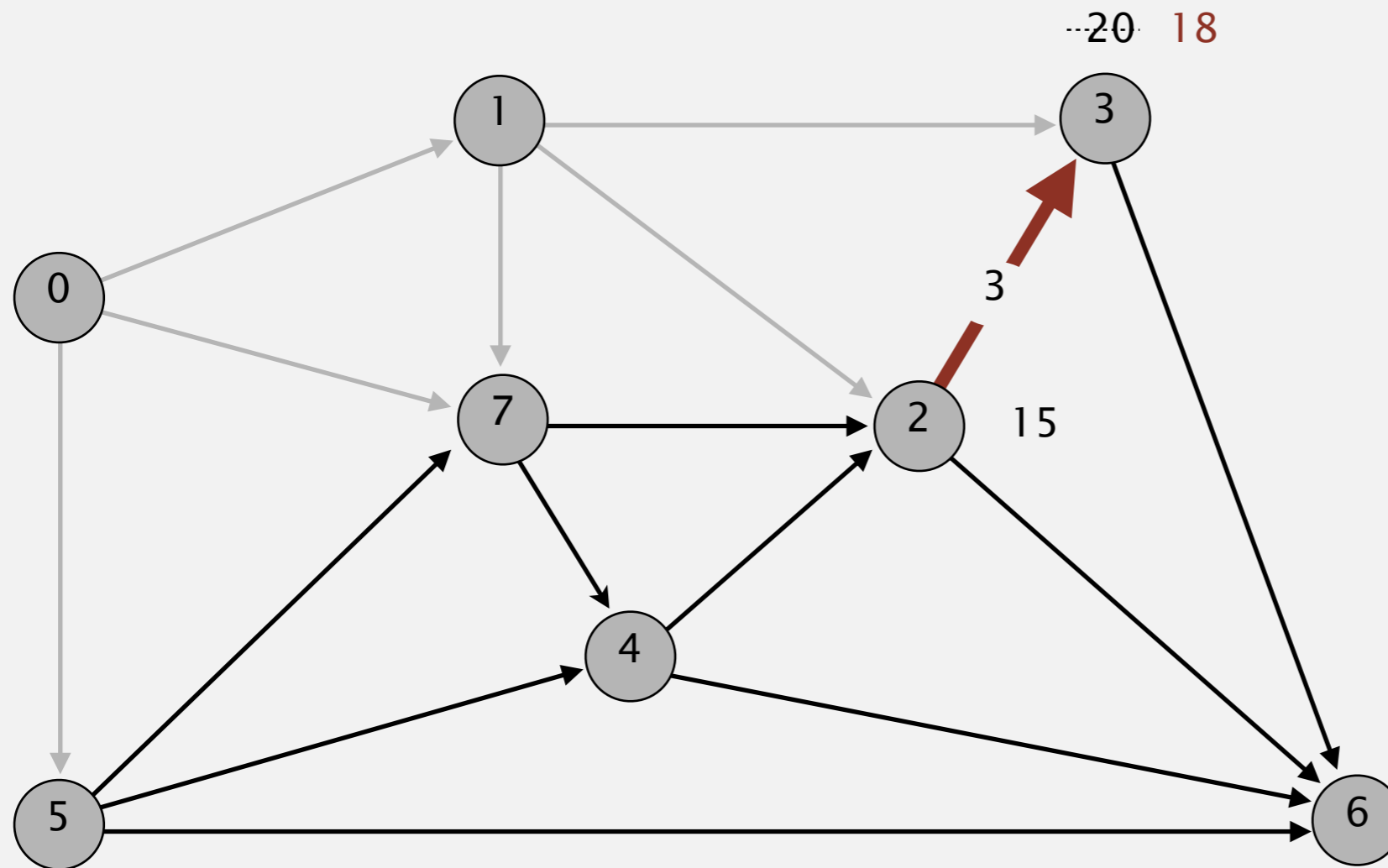
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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4	13.0	5→4
5	9.0	0→5
6	28.0	2→6
7	8.0	0→7

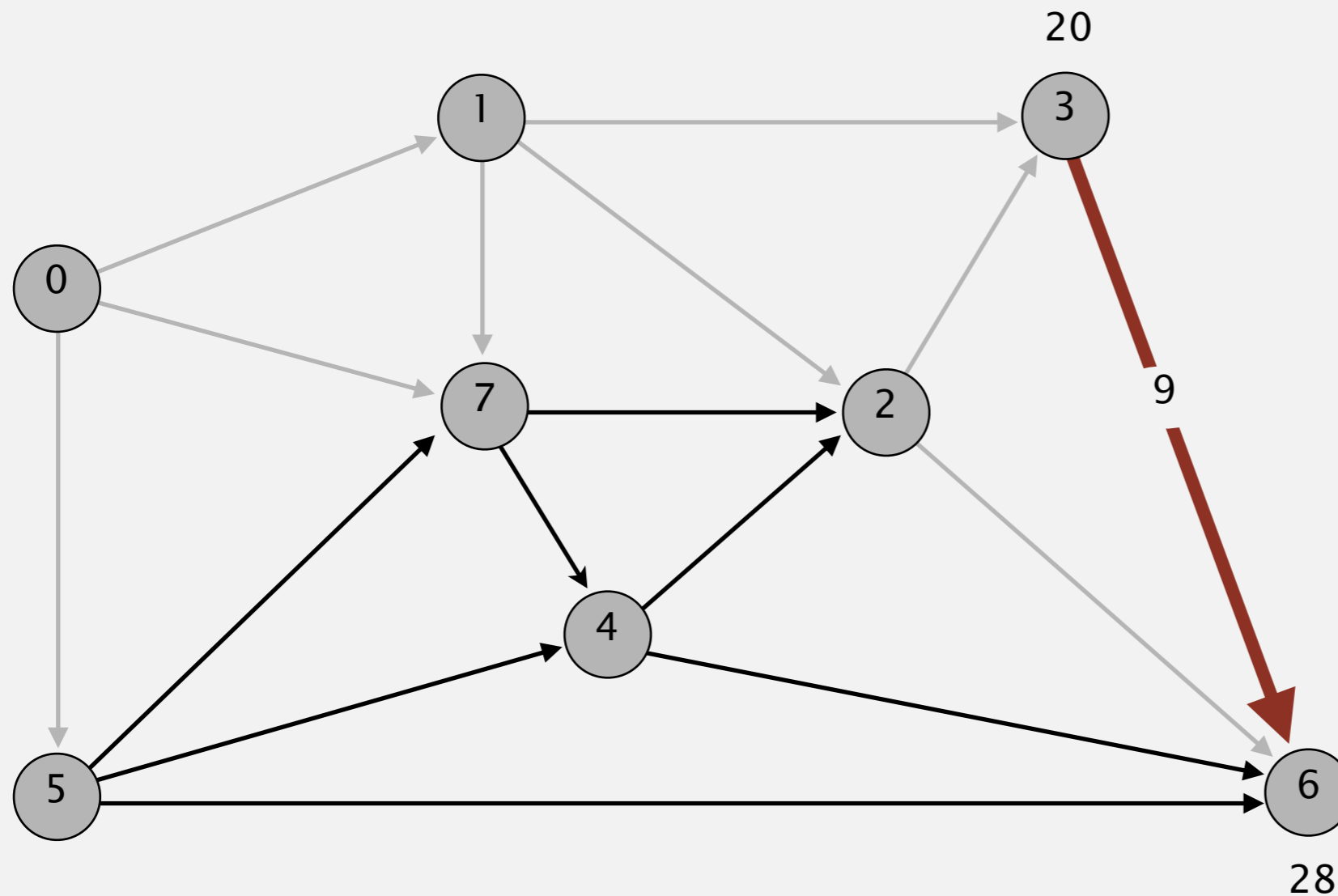
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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3	18.0	1→3
4	13.0	5→4
5	9.0	0→5
6	28.0	2→6
7	8.0	0→7

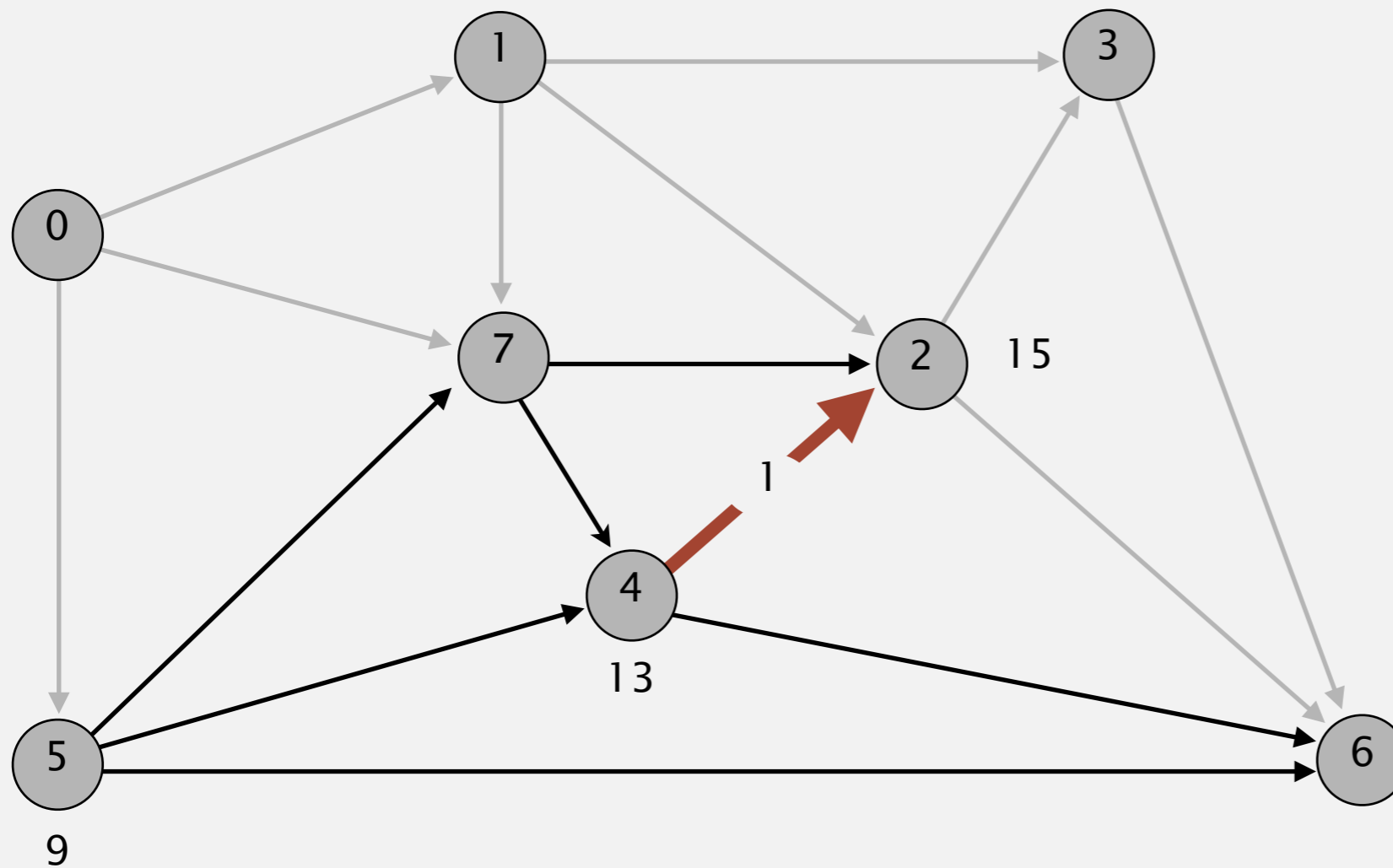
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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4	13.0	5→4
5	9.0	0→5
6	28.0	2→6
7	8.0	0→7

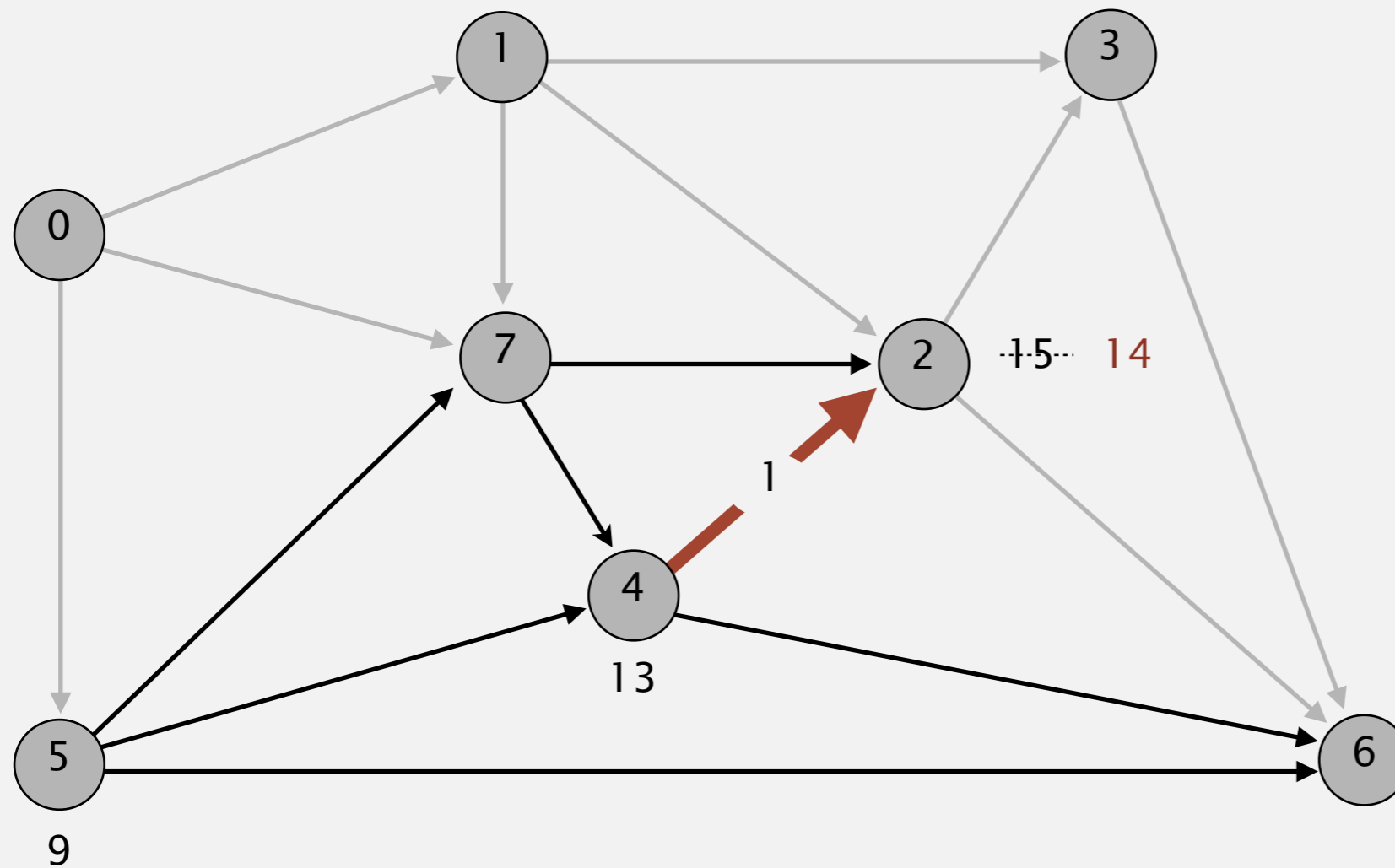
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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4	13.0	5→4
5	9.0	0→5
6	28.0	2→6
7	8.0	0→7

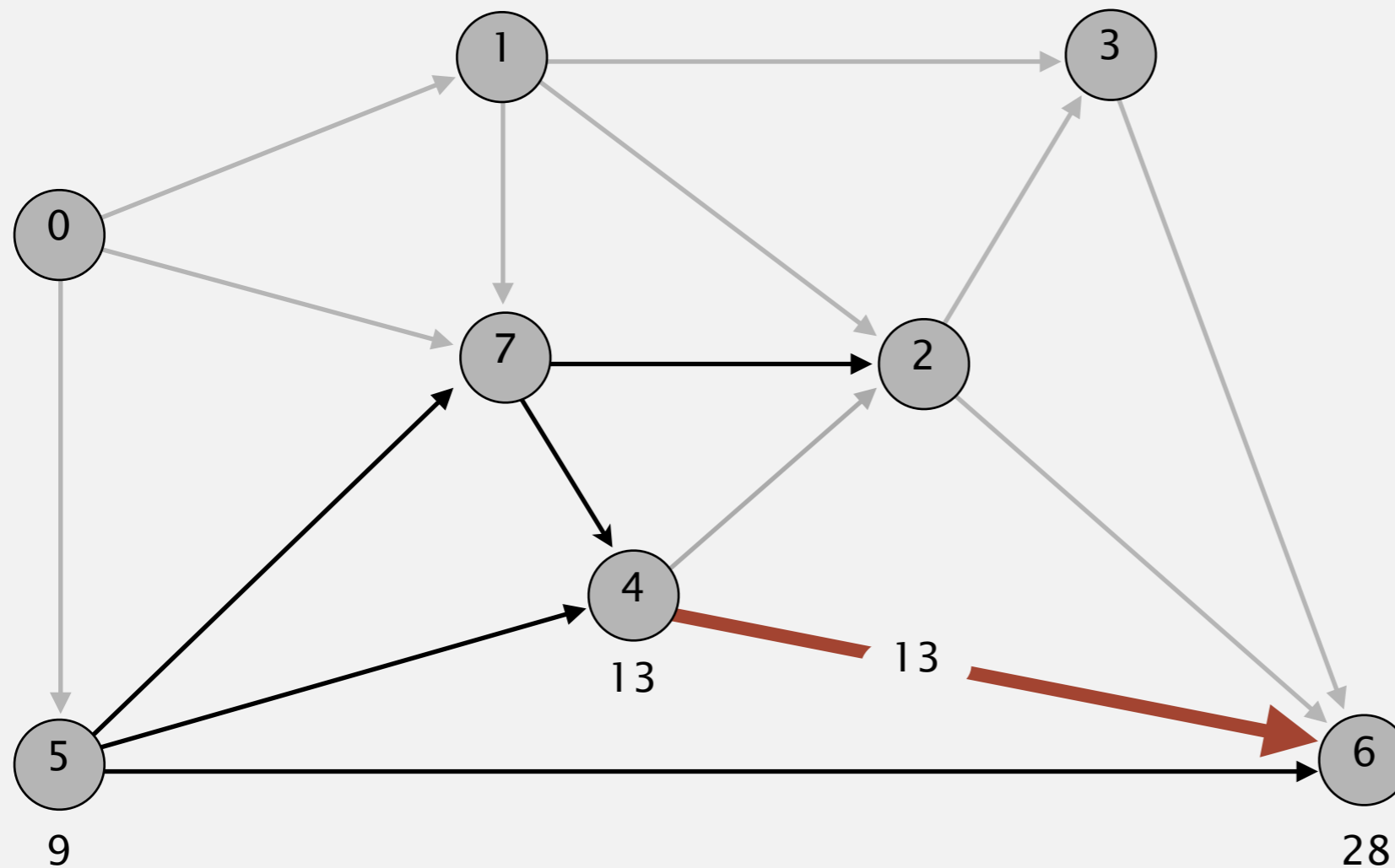
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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4	13.0	5→4
5	9.0	0→5
6	28.0	2→6
7	8.0	0→7

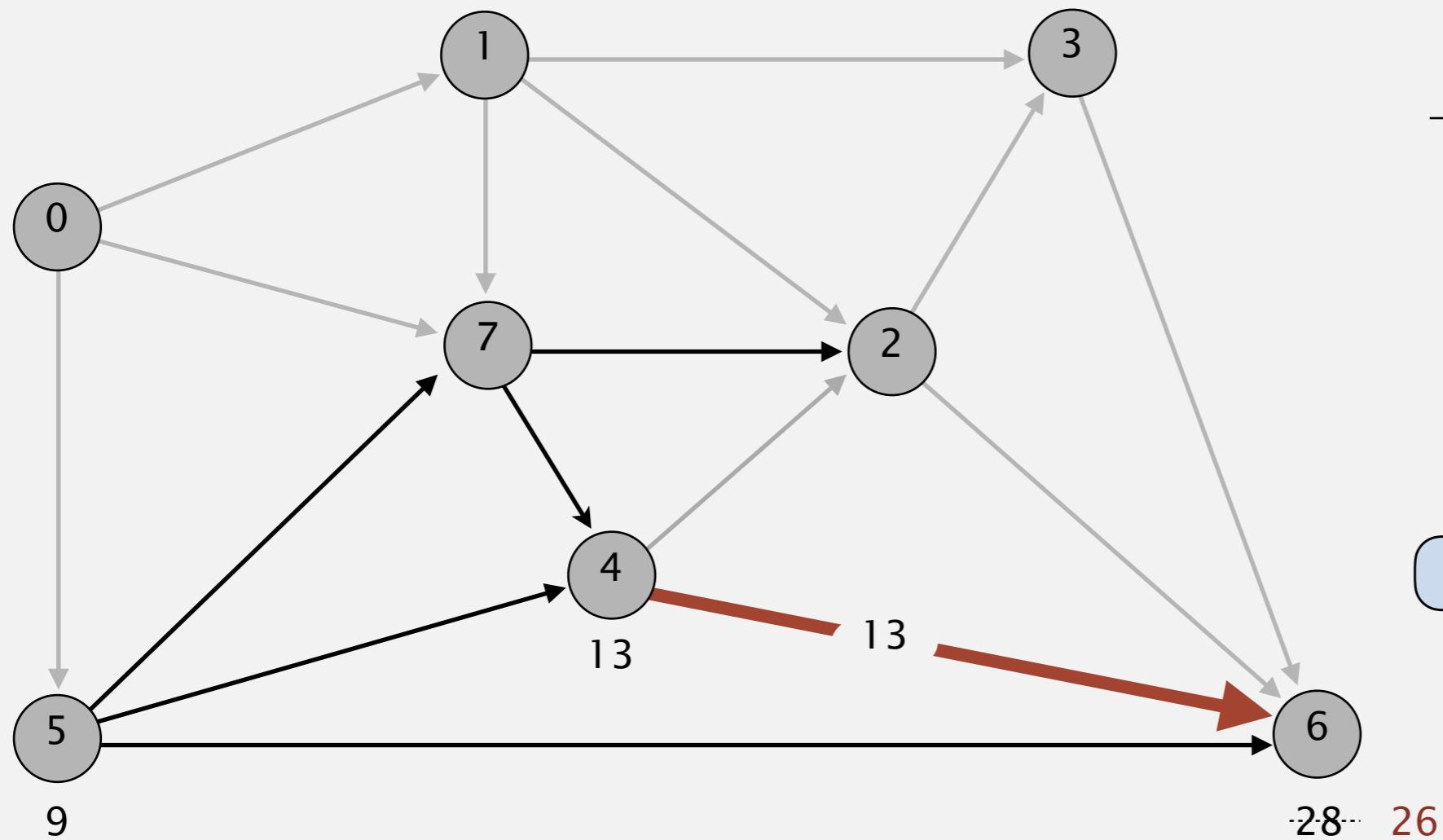
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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4	13.0	5→4
5	9.0	0→5
6	26.0	4→6
7	8.0	0→7

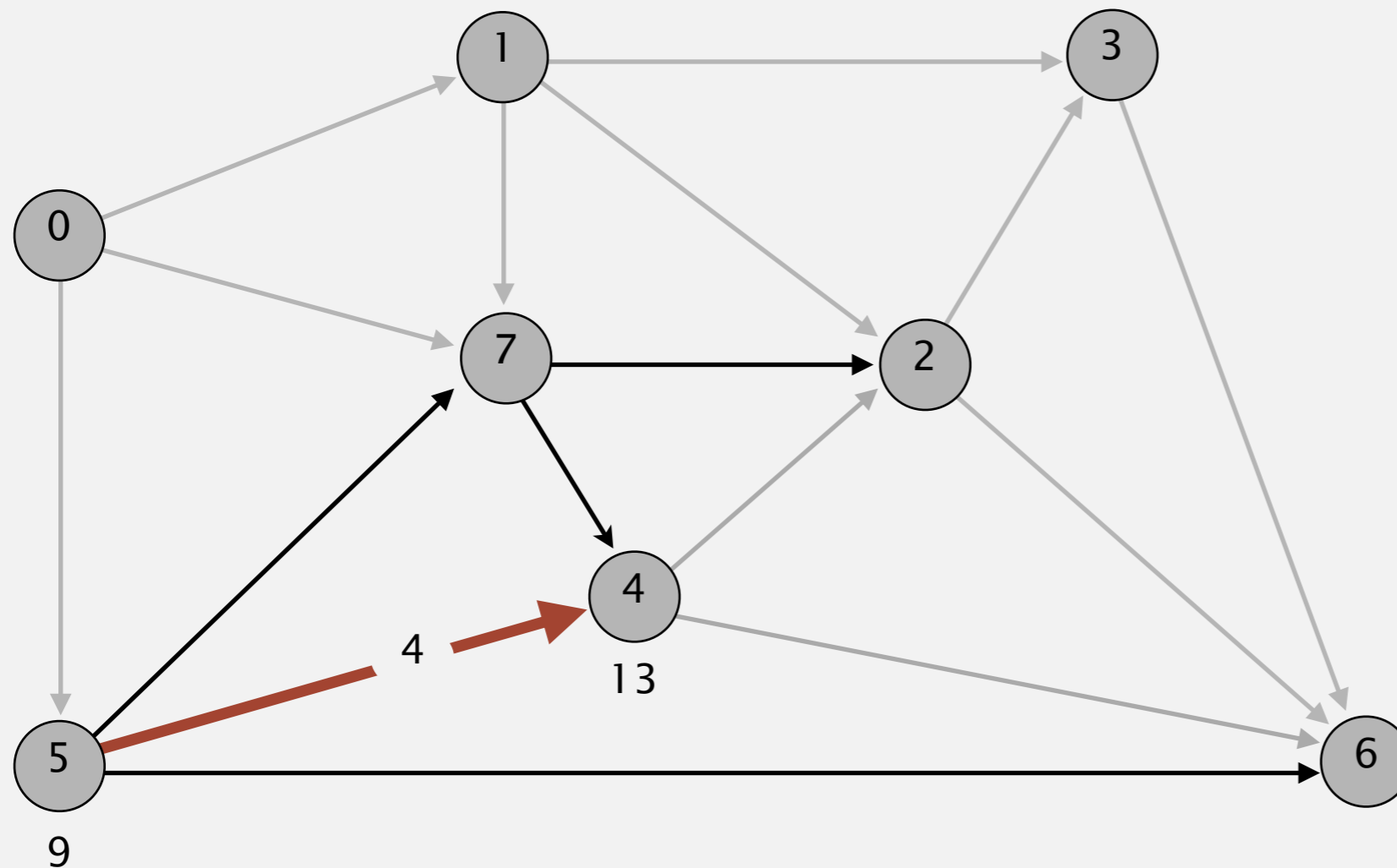
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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5	9.0	0→5
6	26.0	4→6
7	8.0	0→7

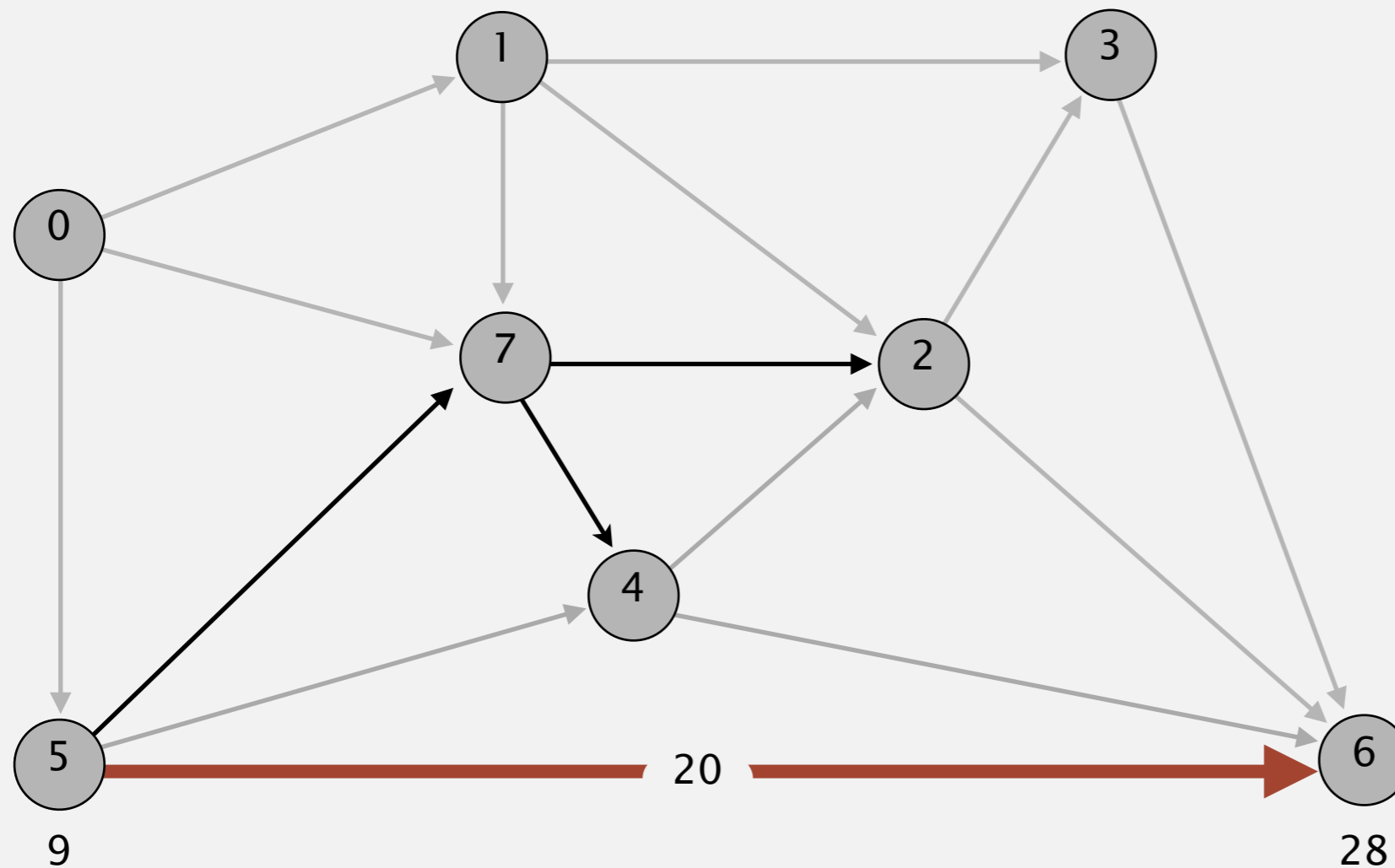
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

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5	9.0	0→5
6	26.0	4→6
7	8.0	0→7

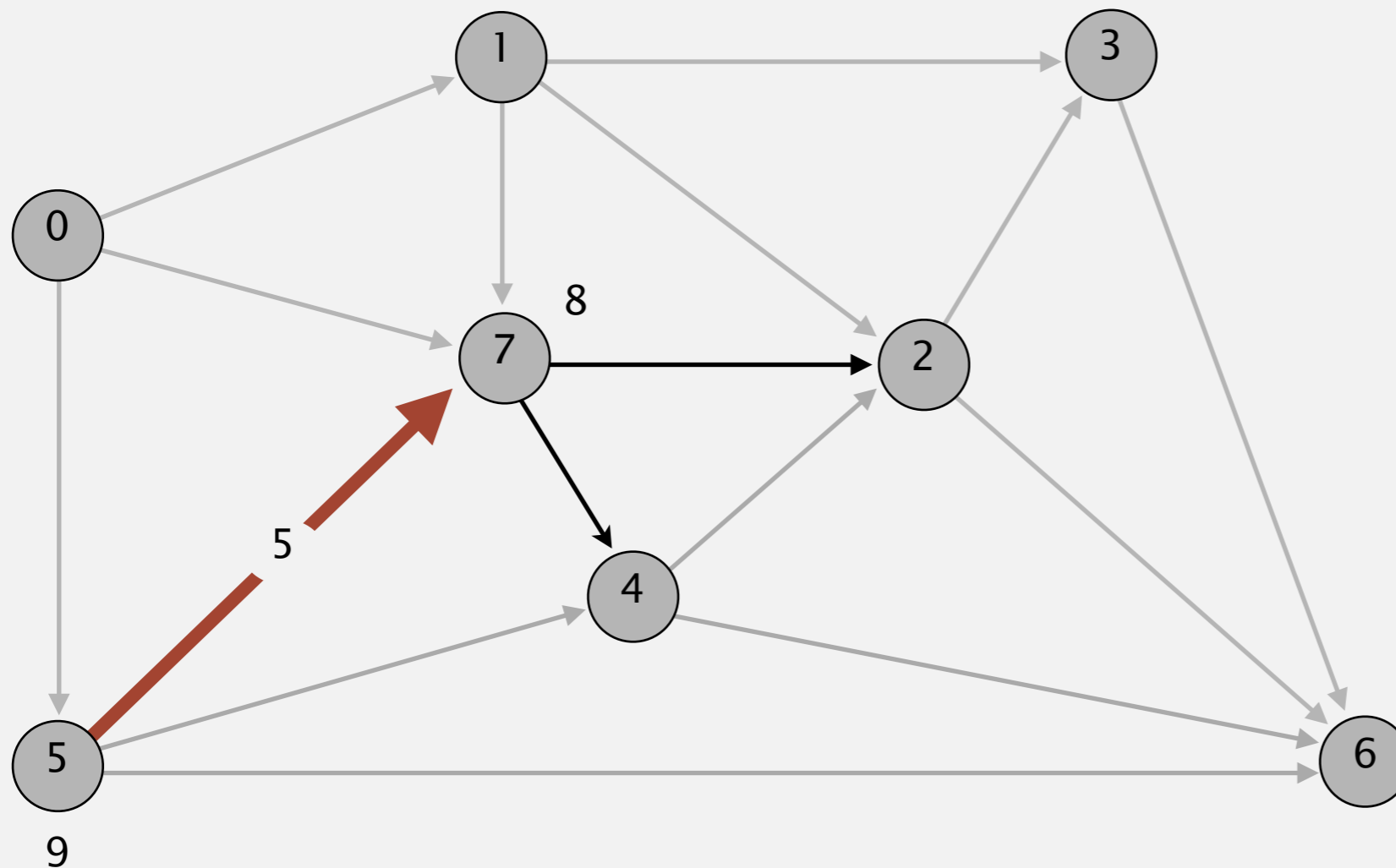
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

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4	13.0	5→4
5	9.0	0→5
6	26.0	4→6
7	8.0	0→7

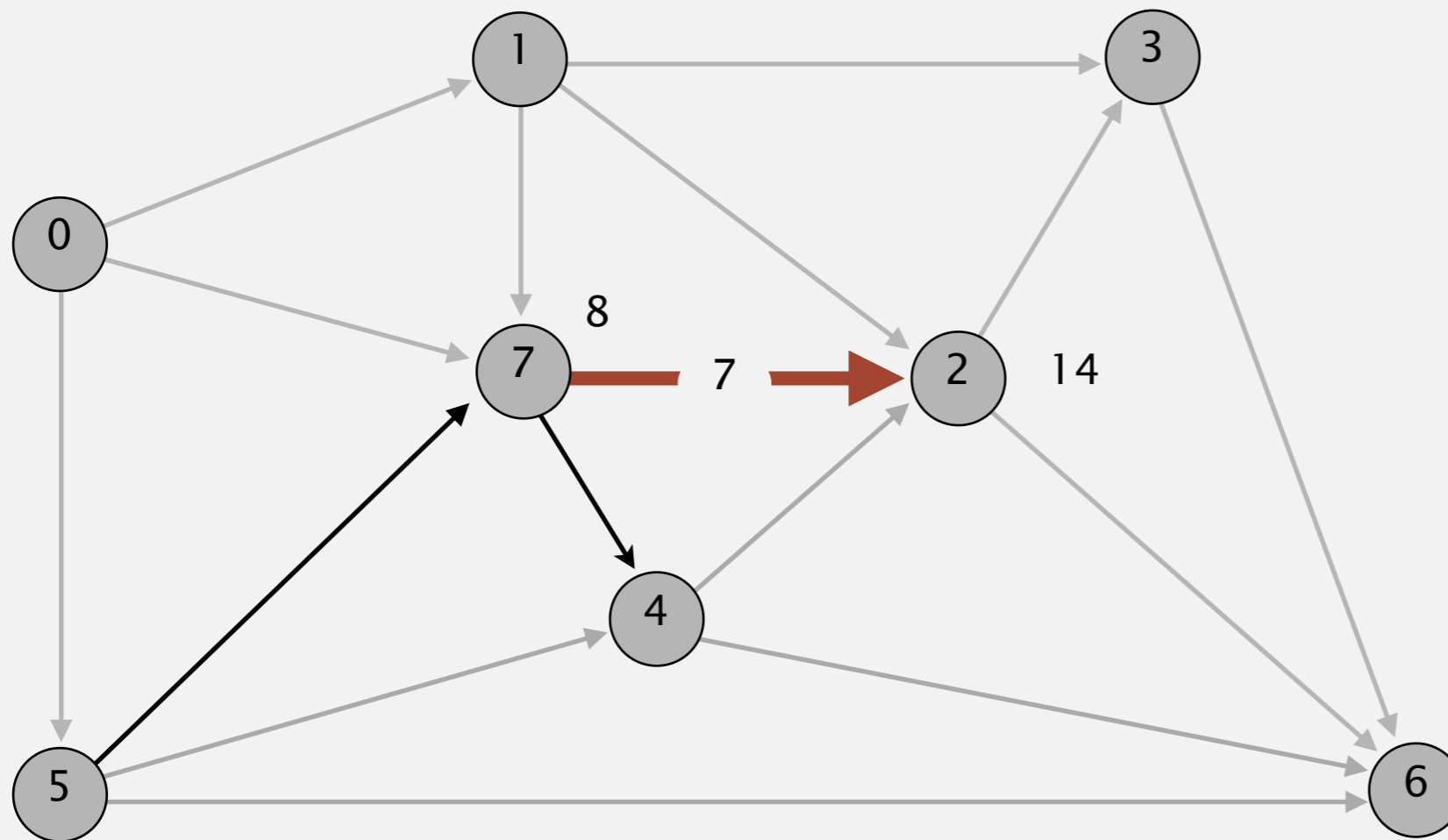
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

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4	13.0	5→4
5	9.0	0→5
6	26.0	4→6
7	8.0	0→7

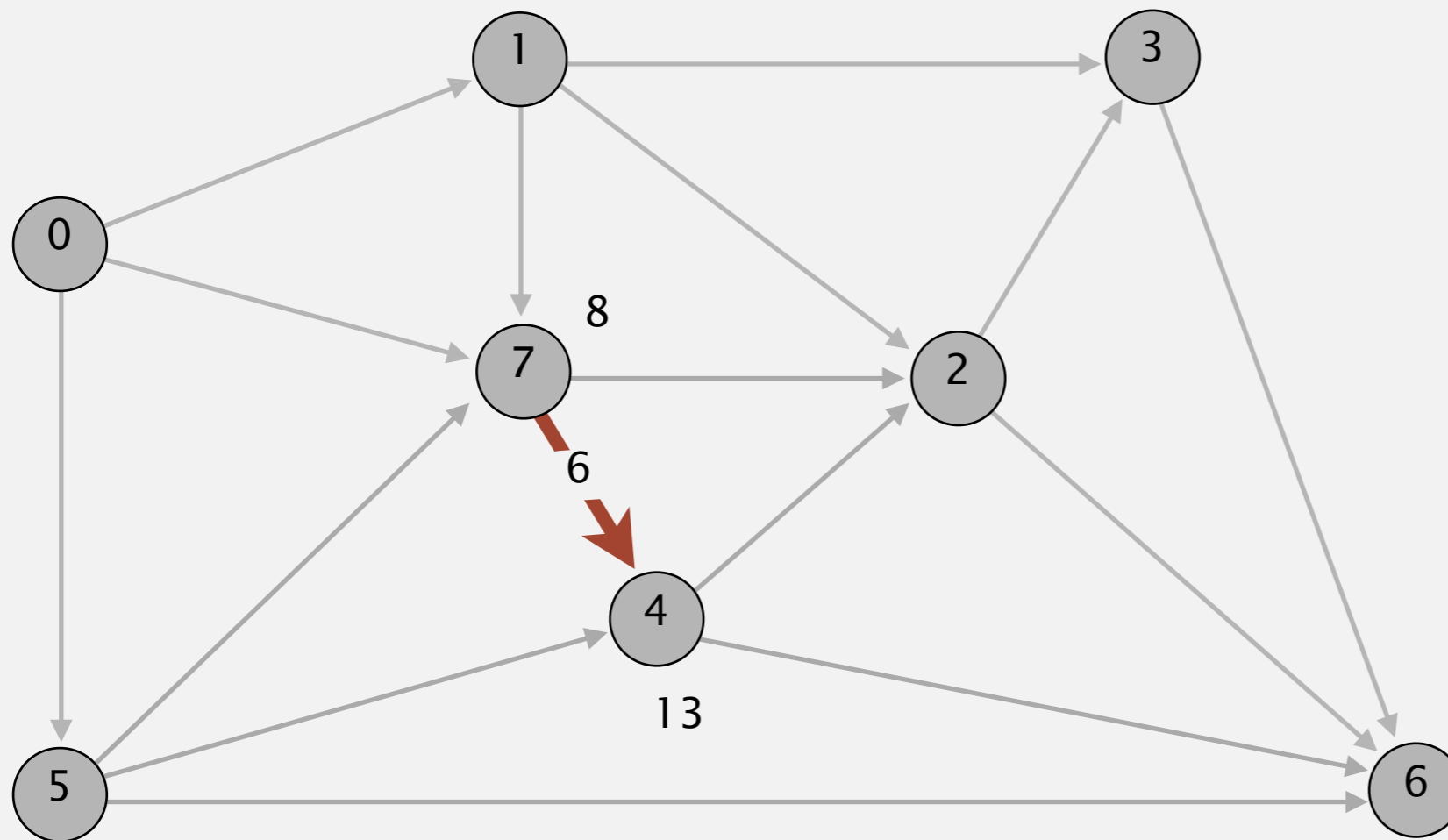
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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1	5.0	0→1
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3	18.0	1→3
4	13.0	5→4
5	9.0	0→5
6	26.0	4→6
7	8.0	0→7

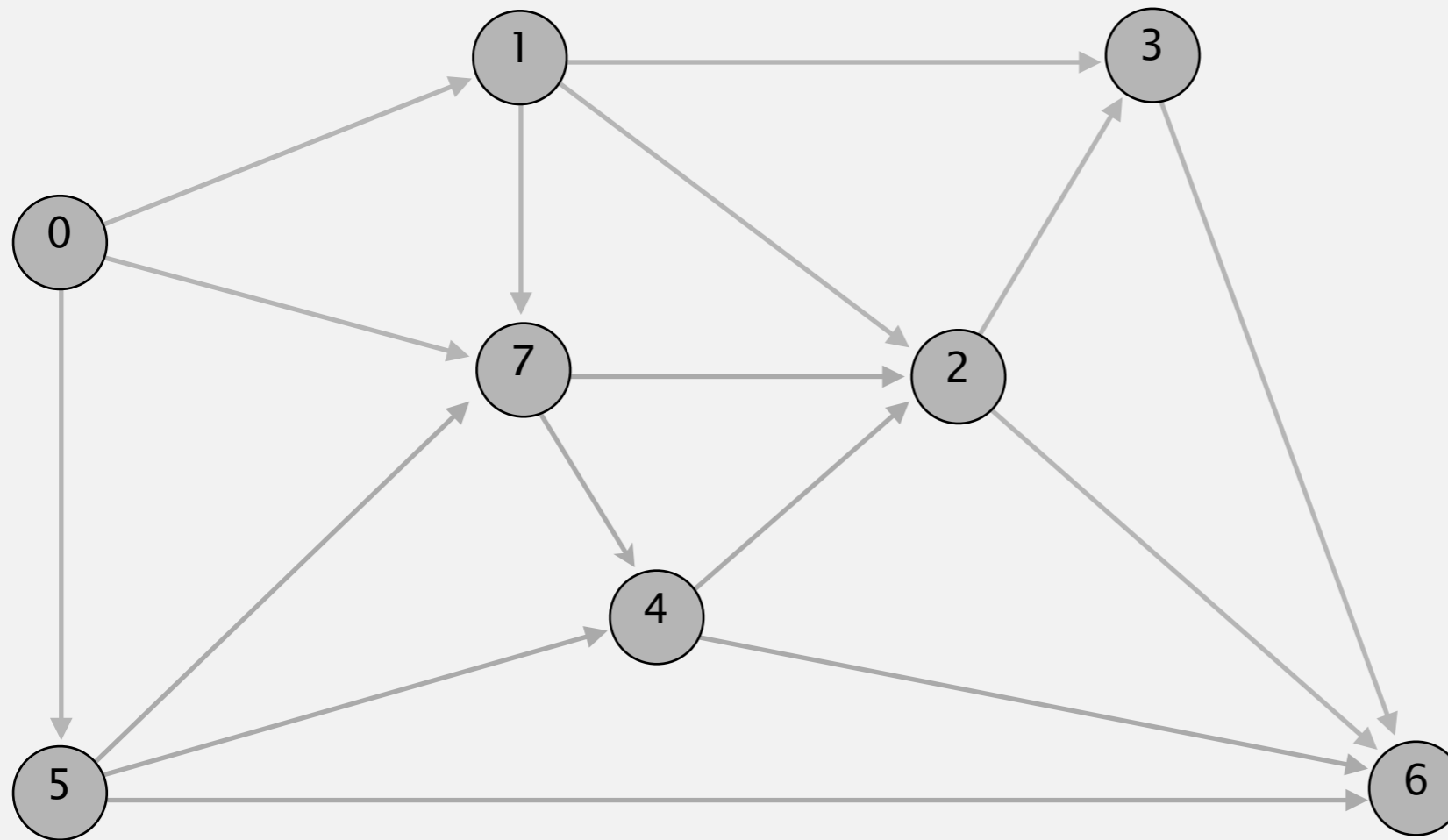
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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1	5.0	0→1
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3	18.0	1→3
4	13.0	5→4
5	9.0	0→5
6	26.0	4→6
7	8.0	0→7

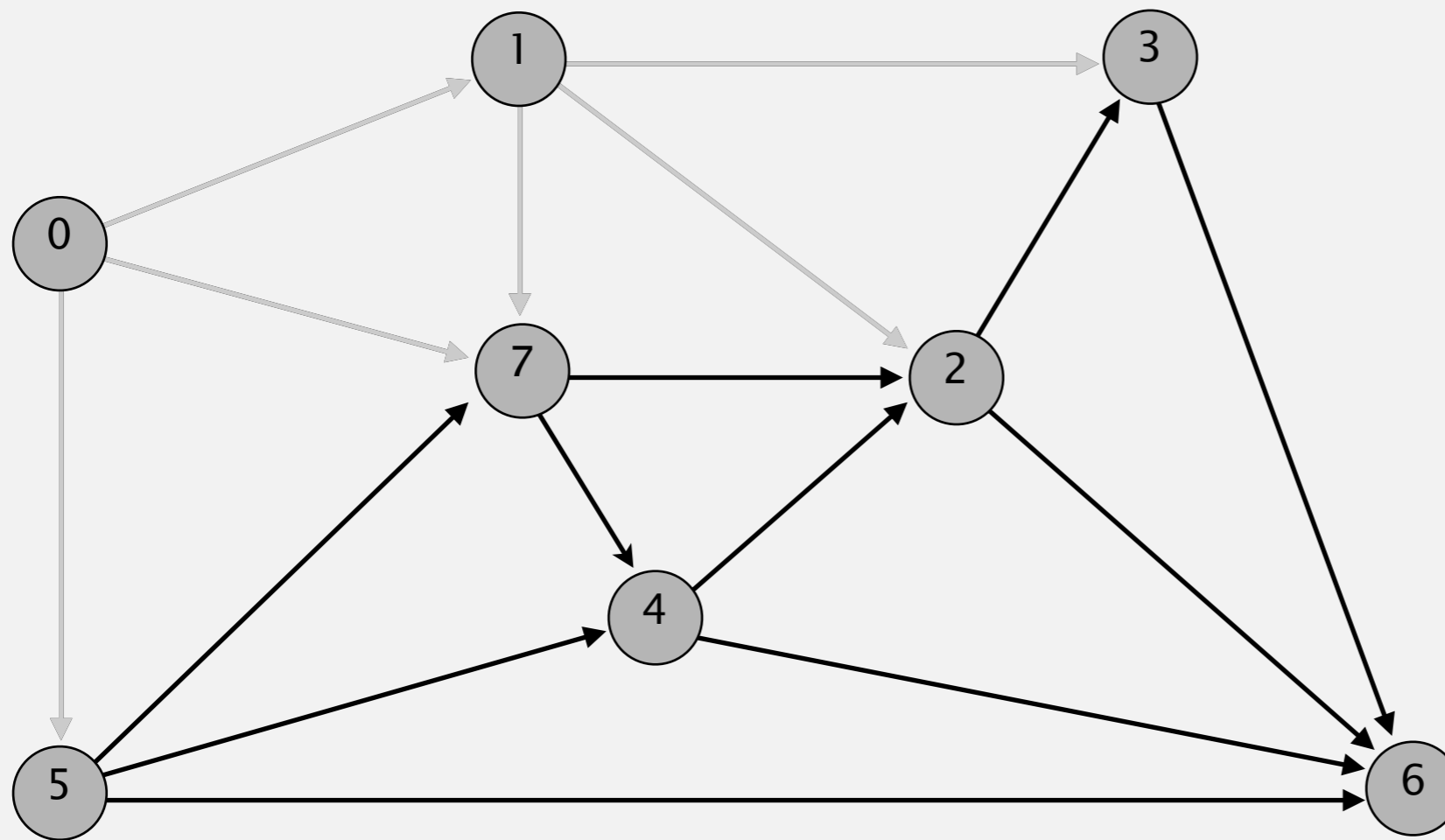
pass 2

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2	14.0	4→2
3	18.0	1→3
4	13.0	5→4
5	9.0	0→5
6	26.0	4→6
7	8.0	0→7

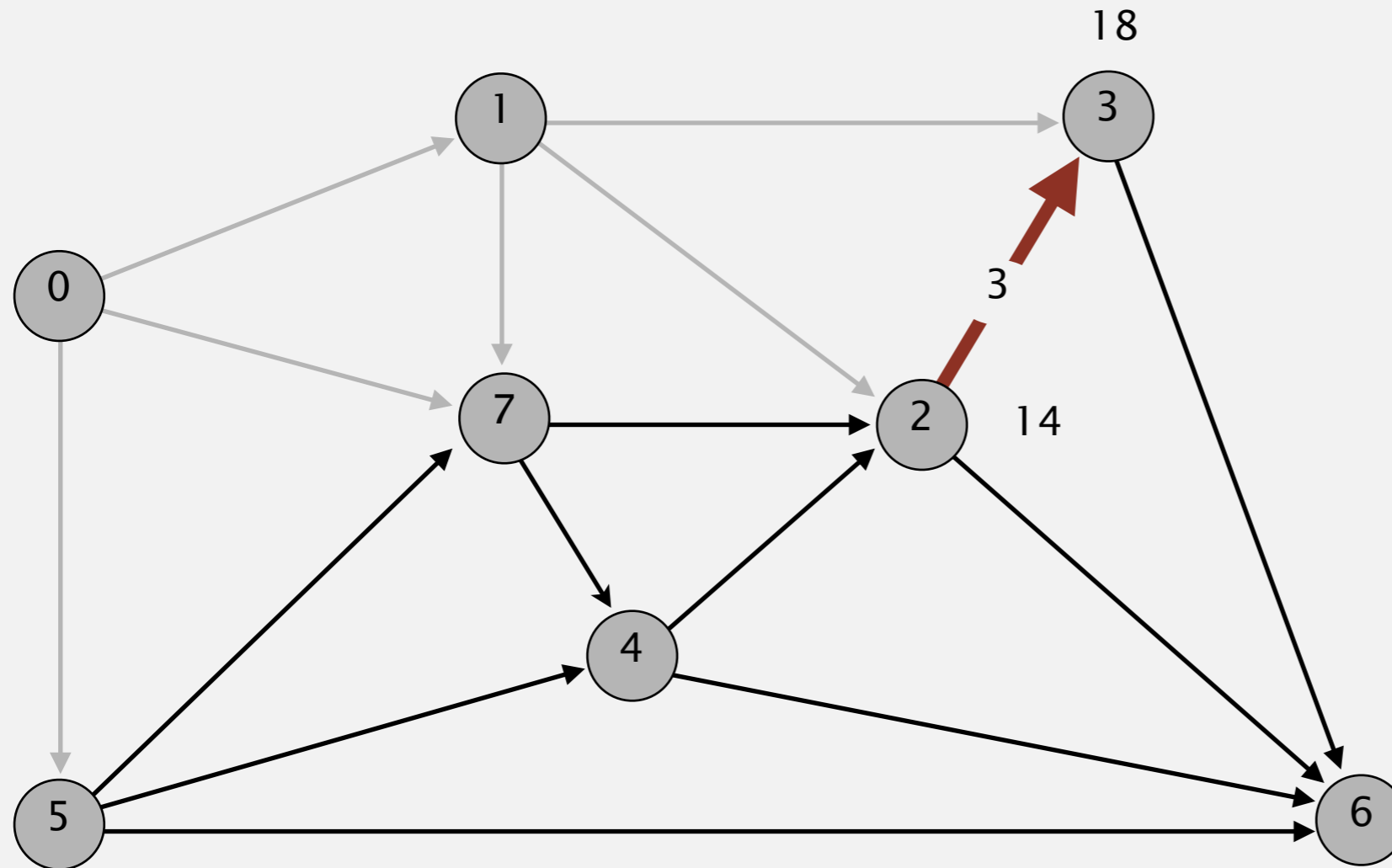
pass 3

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2	14.0	4→2
3	18.0	1→3
4	13.0	5→4
5	9.0	0→5
6	26.0	4→6
7	8.0	0→7

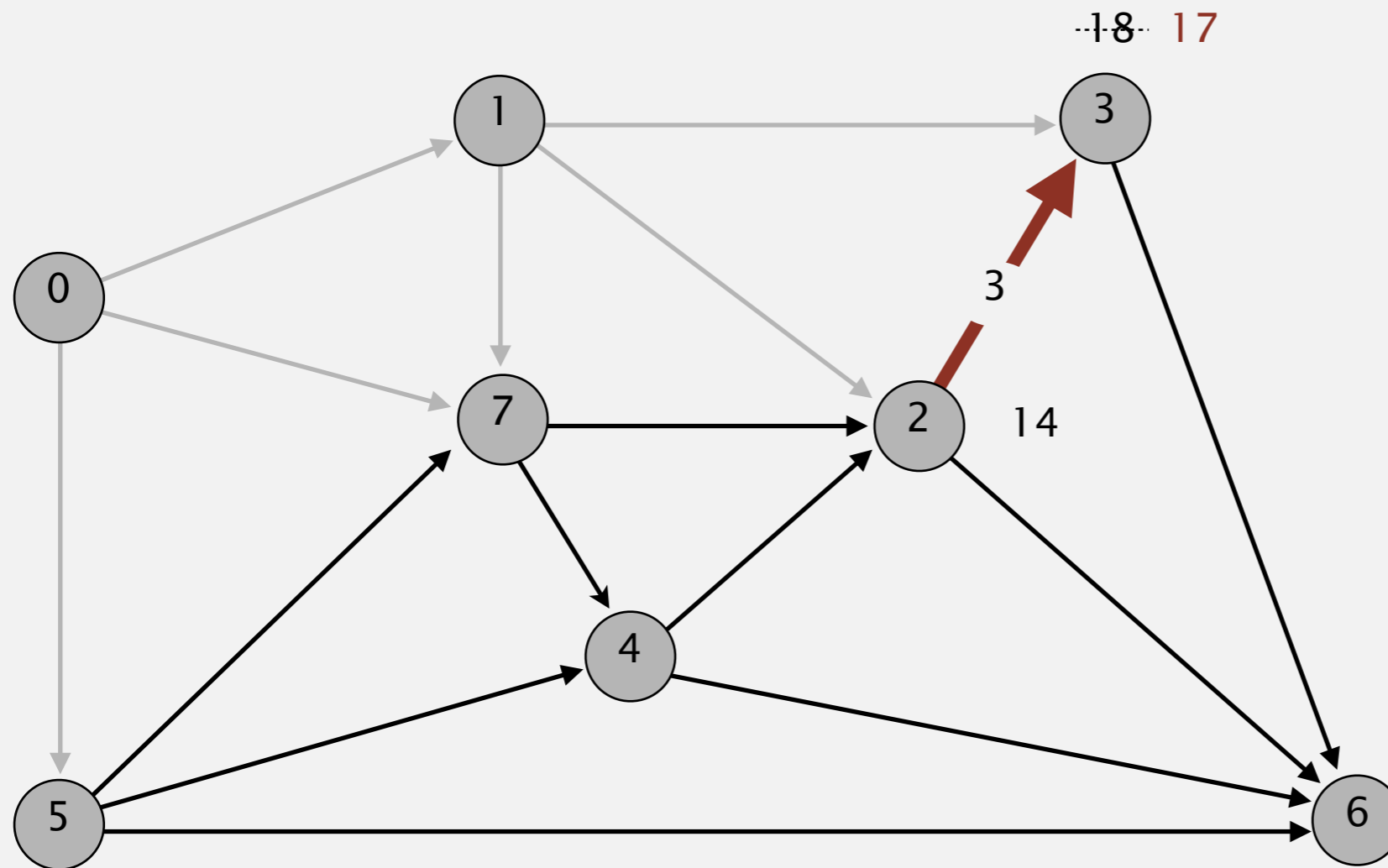
pass 3

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2	14.0	4→2
3	17.0	2→3
4	13.0	5→4
5	9.0	0→5
6	26.0	4→6
7	8.0	0→7

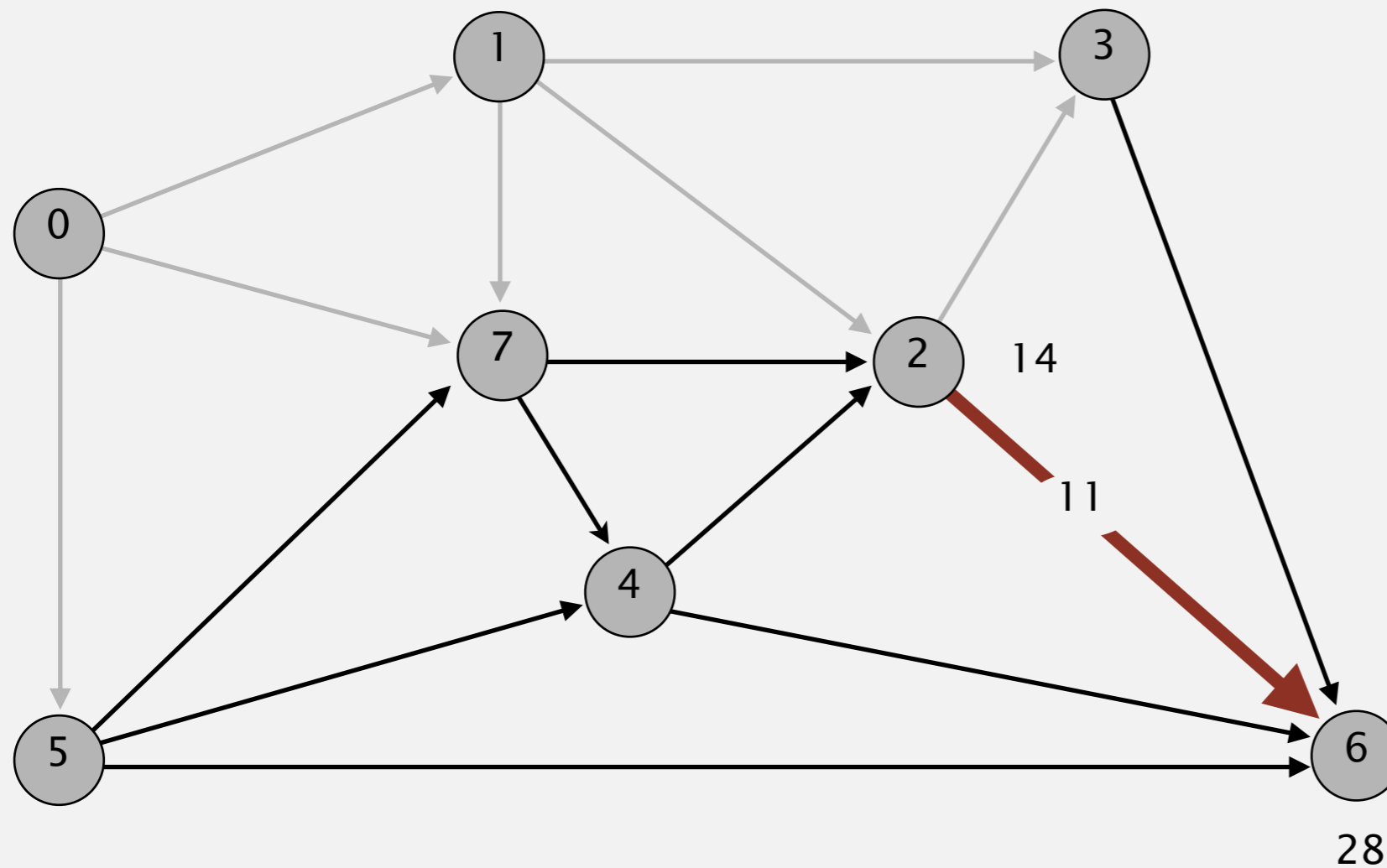
pass 3

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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0	0.0	-
1	5.0	0→1
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3	17.0	2→3
4	13.0	5→4
5	9.0	0→5
6	26.0	4→6
7	8.0	0→7

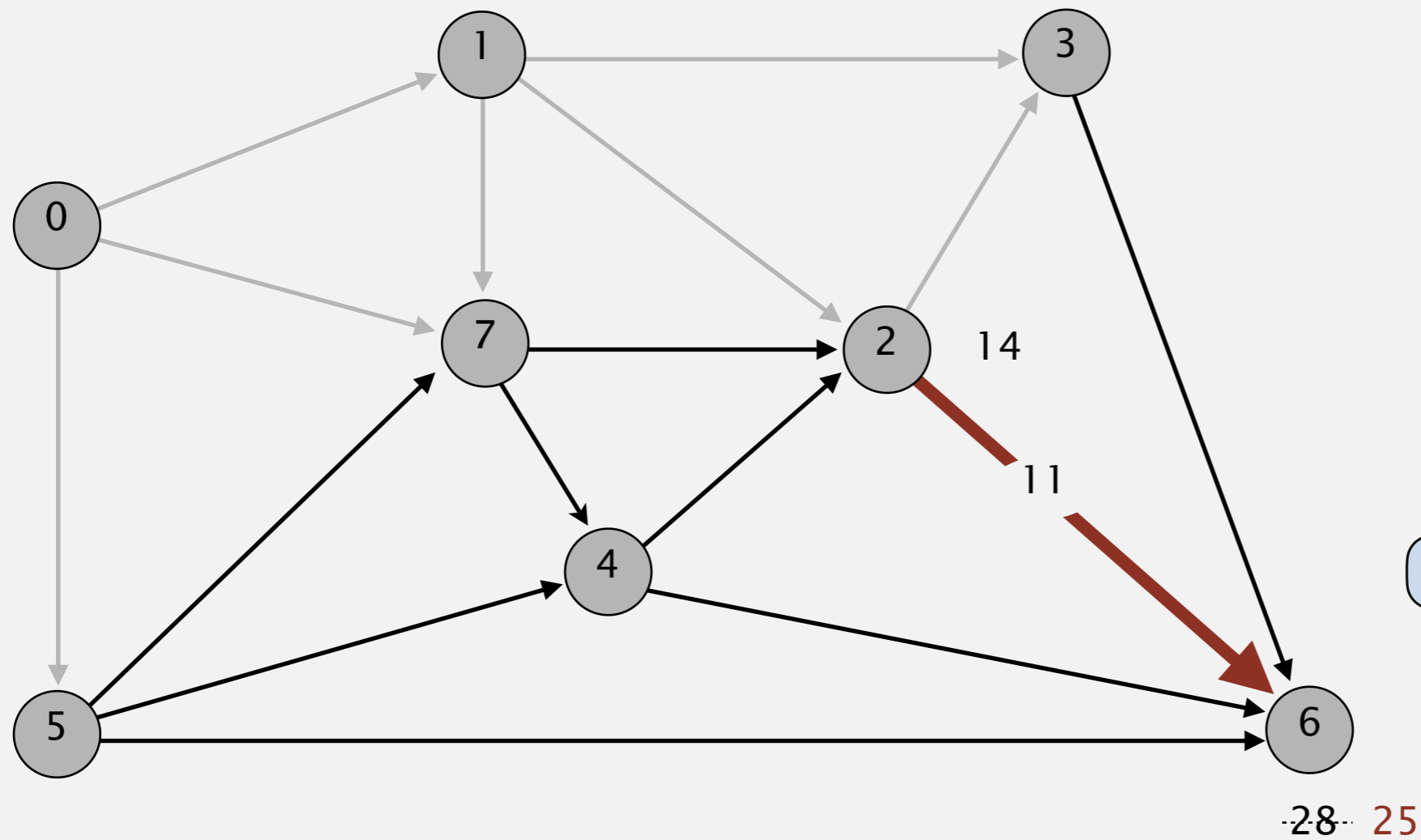
pass 3

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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0	0.0	-
1	5.0	0→1
2	14.0	4→2
3	17.0	2→3
4	13.0	5→4
5	9.0	0→5
6	25.0	2→6
7	8.0	0→7

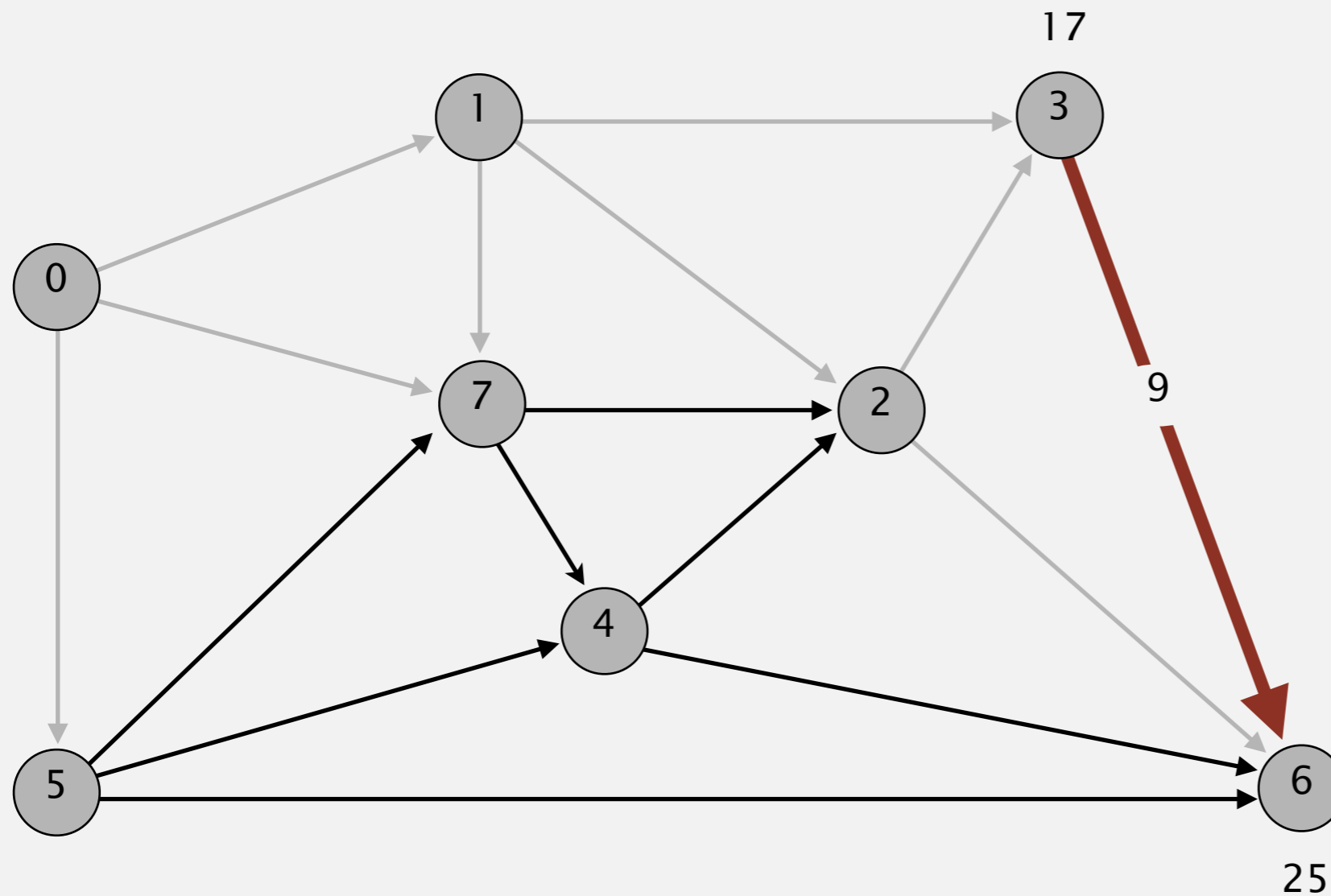
pass 3

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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6	25.0	2→6
7	8.0	0→7

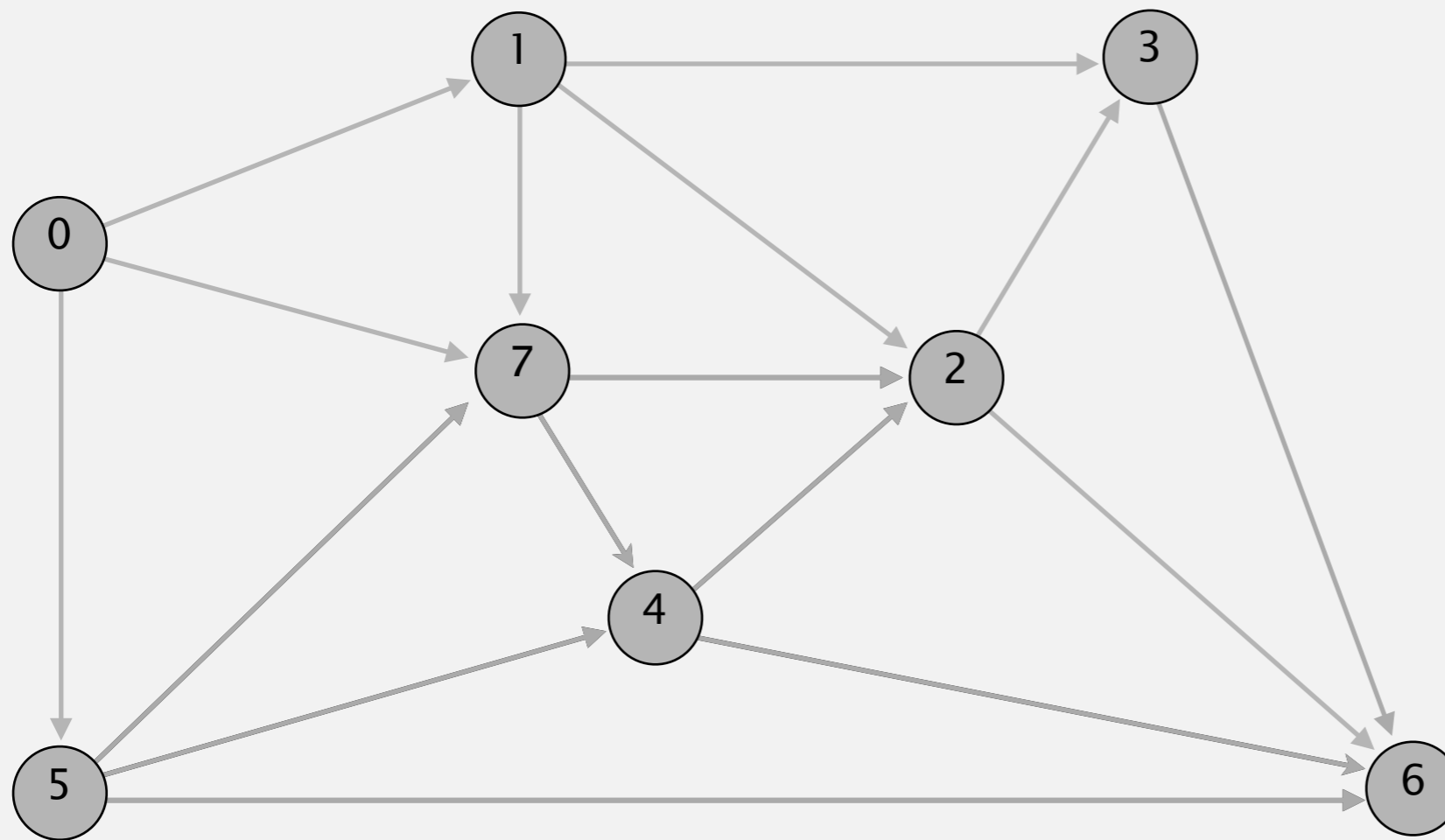
pass 3

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



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0	0.0	-
1	5.0	0→1
2	14.0	4→2
3	17.0	2→3
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5	9.0	0→5
6	25.0	2→6
7	8.0	0→7

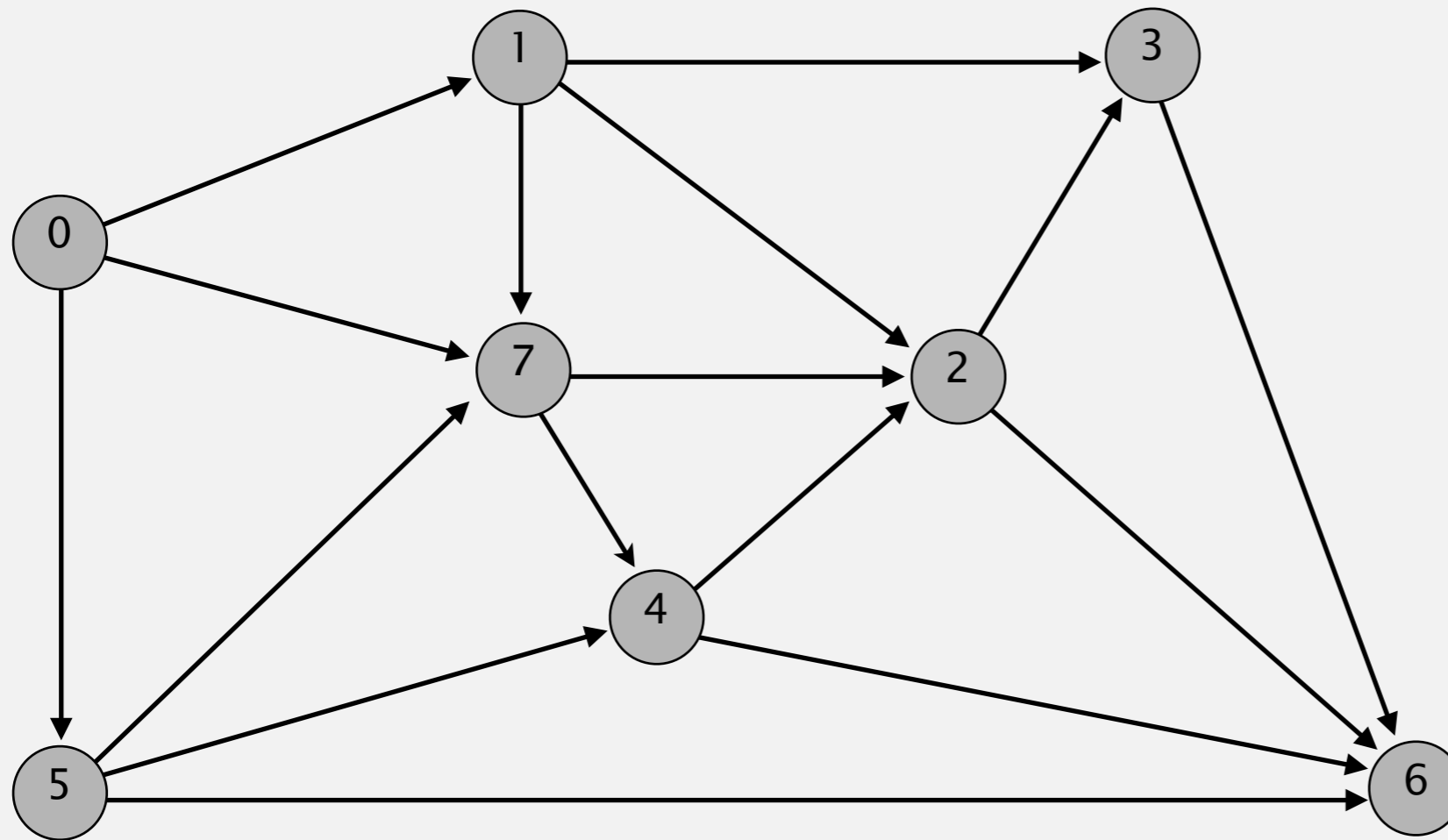
pass 3

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2	14.0	4→2
3	17.0	2→3
4	13.0	5→4
5	9.0	0→5
6	25.0	2→6
7	8.0	0→7

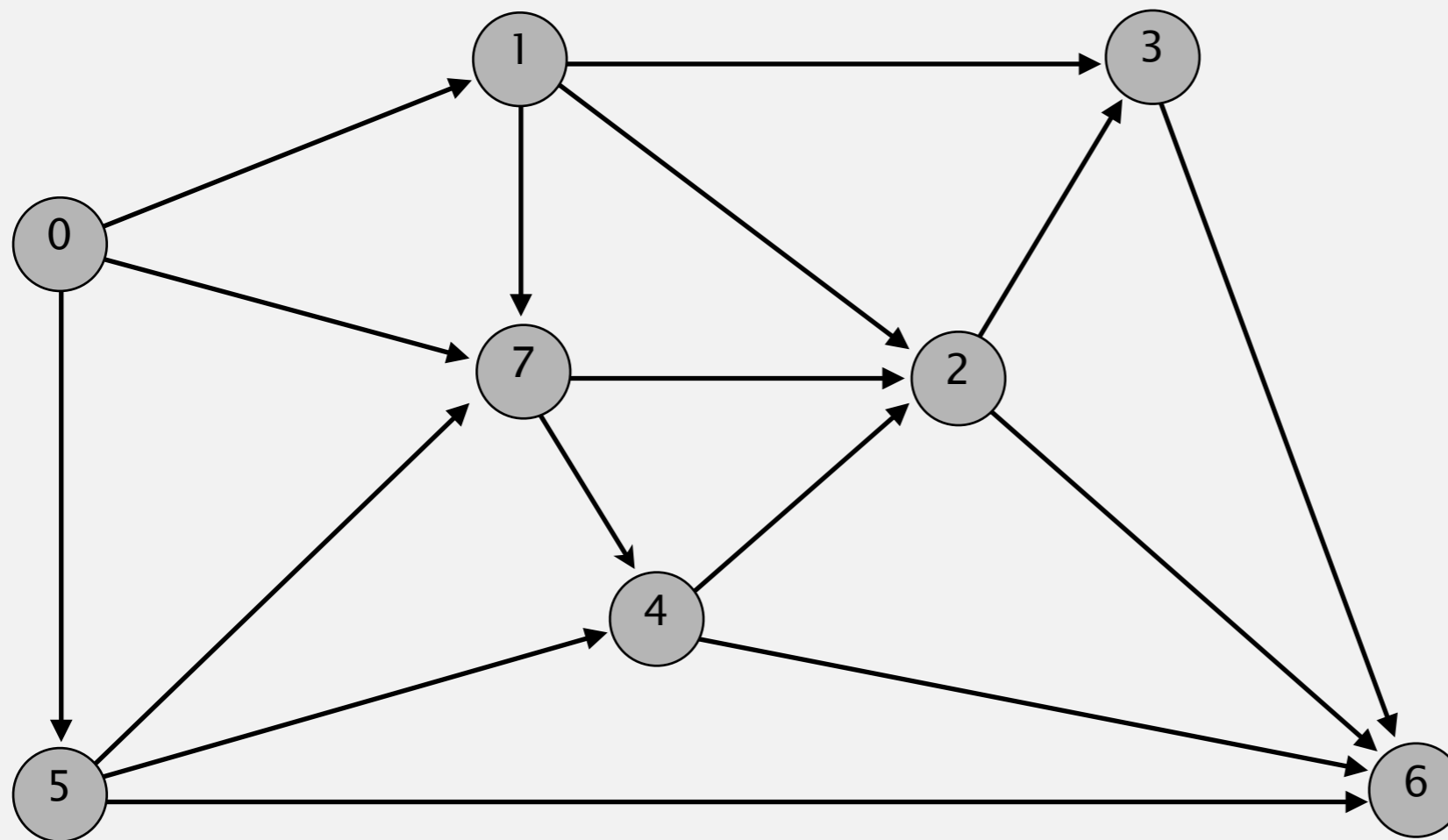
pass 4 (no changes)

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2	14.0	4→2
3	17.0	2→3
4	13.0	5→4
5	9.0	0→5
6	25.0	2→6
7	8.0	0→7

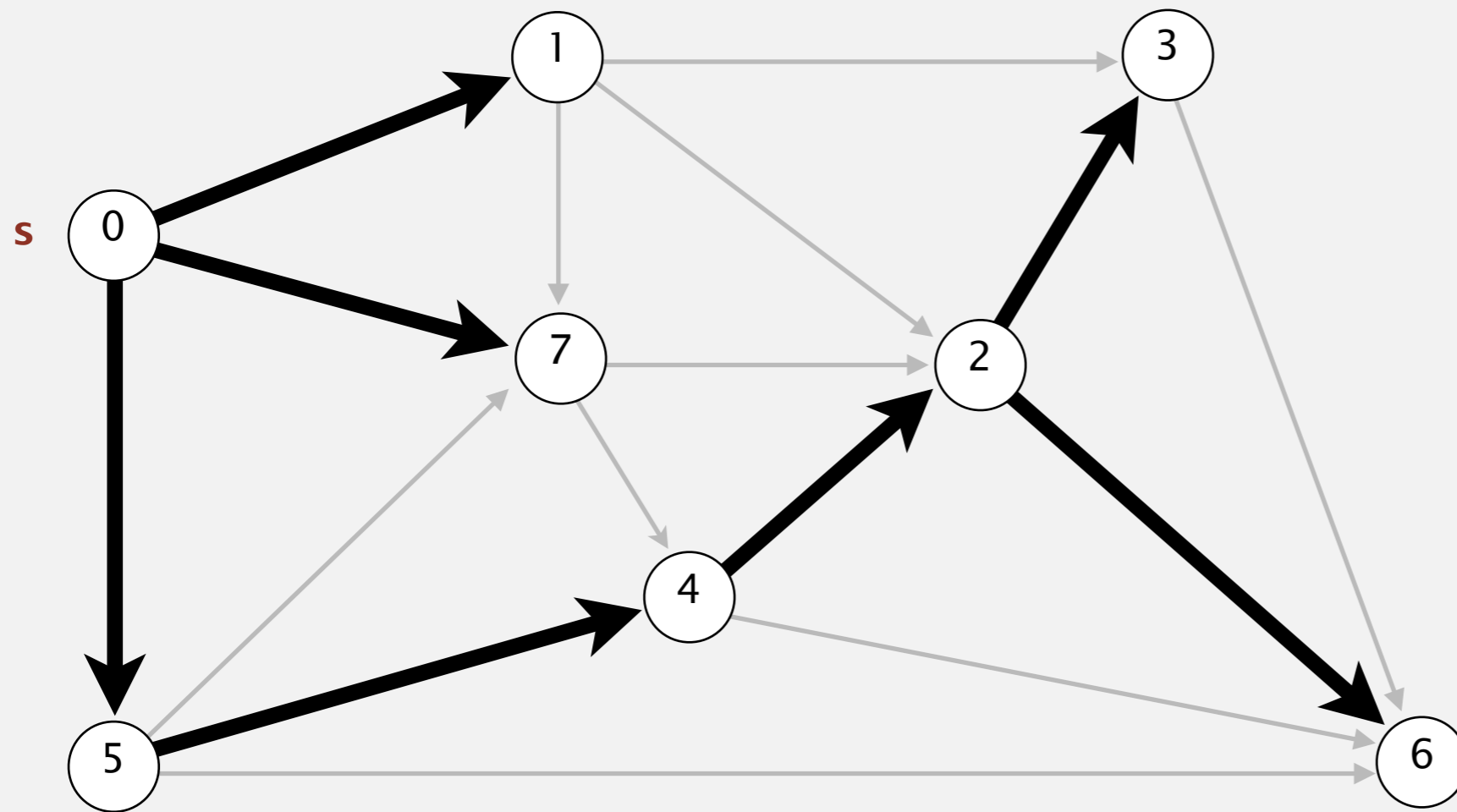
passes 5, 6, and 7 (no changes)

0→1 0→5 0→7 1→2 1→3 1→7 2→3 2→6 3→6 4→2 4→6 5→4 5→6 5→7 7→2 7→4



Bellman-Ford algorithm demo

Repeat $V - 1$ times: relax all E edges.



v	distTo[]	edgeTo[]
0	0.0	-
1	5.0	0→1
2	14.0	4→2
3	17.0	2→3
4	13.0	5→4
5	9.0	0→5
6	25.0	2→6
7	8.0	0→7

shortest-paths tree from vertex s