

L12

Arbitrage

abhi shelat

Currency code ▲ ▼	Currency name ▲ ▼	Units per USD	USD per Unit
USD	US Dollar	1.0000000000	1.0000000000
EUR	Euro	0.8783121137	1.1385474303
GBP	British Pound	0.6956087704	1.4375896950
INR	Indian Rupee	66.1909310706	0.0151078098
AUD	Australian Dollar	1.3050318080	0.7662648480
CAD	Canadian Dollar	1.2997506294	0.7693783541
SGD	Singapore Dollar	1.3478961522	0.7418969172
CHF	Swiss Franc	0.9590451582	1.0427037678
MYR	Malaysian Ringgit	3.8700000000	0.2583979328
JPY	Japanese Yen	112.5375383115	0.0088859239
CNY	Chinese Yuan Renminbi	6.4492409303	0.1550570076
NZD	New Zealand Dollar	1.4480018872	0.6906068347
THB	Thai Baht	35.1005319022	0.0284895968
HUF	Hungarian Forint	275.7012427385	0.0036271146
AED	Emirati Dirham	3.6730000000	0.2722570106
HKD	Hong Kong Dollar	7.7563973683	0.1289258341
MXN	Mexican Peso	17.3168505322	0.0577472213
ZAR	South African Rand	14.7201431400	0.0679341220
PHP	Philippine Peso	45.9250000000	0.0217746326

XE Currency Table: AED - Emirati Dirham

Mid-market rates as of 2016-03-31 17:40 UTC

Currency code ▲▼	Currency name ▲▼	Units per EUR	EUR per Unit
USD	US Dollar	1.1386632306	0.8762227907
EUR	Euro	1.0000000000	1.0000000000
GBP	British Pound	0.7921136388	1.2624451227
INR	Indian Rupee	75.3658843112	0.0132888030
AUD	Australian Dollar	1.4859581878	0.6729873514
CAD	Canadian Dollar	1.4796754127	0.6758238945
SGD	Singapore Dollar	1.5347639238	0.6515960060
CHF	Swiss Franc	1.0917416715	0.9159576012
MYR	Malaysian Ringgit	4.4140052400	0.2265516114
JPY	Japanese Yen	128.1388820287	0.0078040325
CNY	Chinese Yuan Renminbi	7.3411003512	0.1362193612
NZD	New Zealand Dollar	1.8484648003	0.6065250248
THB	Thai Baht	39.9627318192	0.0250233143
HUF	Hungarian Forint	313.9042436792	0.0031856649
AED	Emirati Dirham	4.1823100458	0.2391023117

Mid-market rates as of 2016-03-31 17:39 UTC

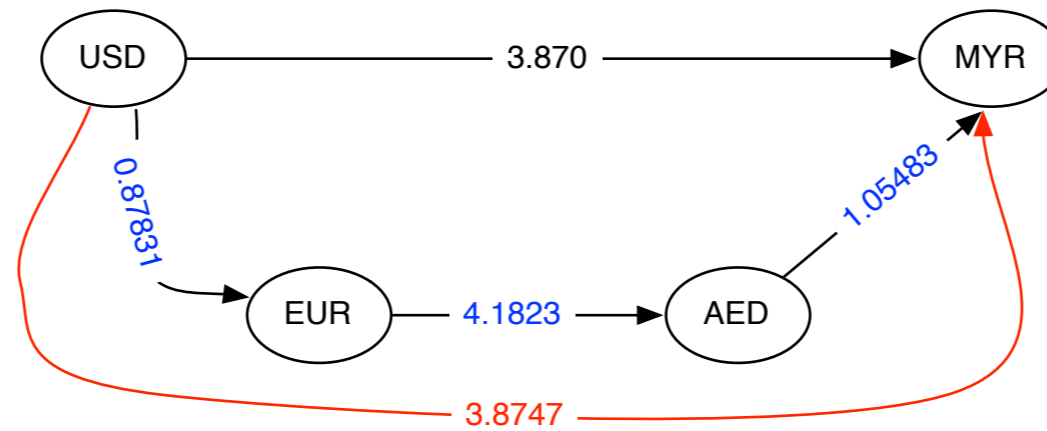
Currency code ▲▼	Currency name ▲▼	Units per AED	AED per Unit
USD	US Dollar	0.2722570108	3.6730000000
EUR	Euro	0.2391289974	4.1815433177
GBP	British Pound	0.1893997890	5.2798369266
INR	Indian Rupee	18.0207422309	0.0554918100
AUD	Australian Dollar	0.3552895418	2.8145257760
CAD	Canadian Dollar	0.3538334124	2.8261987234
SGD	Singapore Dollar	0.3669652245	2.7250538559
CHF	Swiss Franc	0.2610688193	3.8304105746
MYR	Malaysian Ringgit	1.0548325819	0.9480177576
JPY	Japanese Yen	30.6399242607	0.0328371564
CNY	Chinese Yuan Renminbi	1.7555154332	0.5696332719
NZD	New Zealand Dollar	0.3941937299	2.5355237088
THB	Thai Baht	9.5553789460	0.1046530970
HUF	Hungarian Forint	75.0637936939	0.0133220019
AED	Emirati Dirham	1.0000000000	1.0000000000

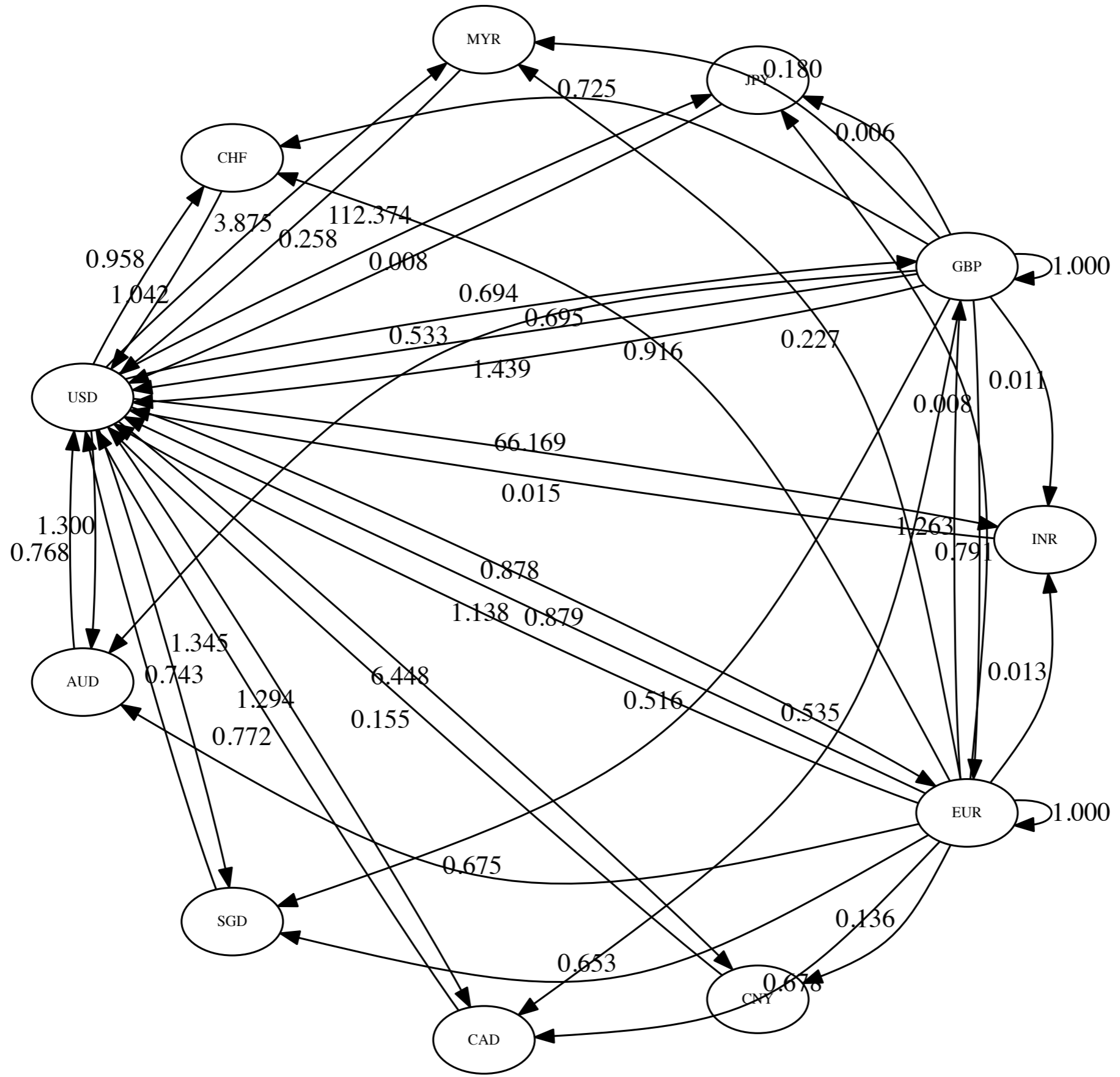
Mid-market rates as of 2016-03-31 17:40 UTC

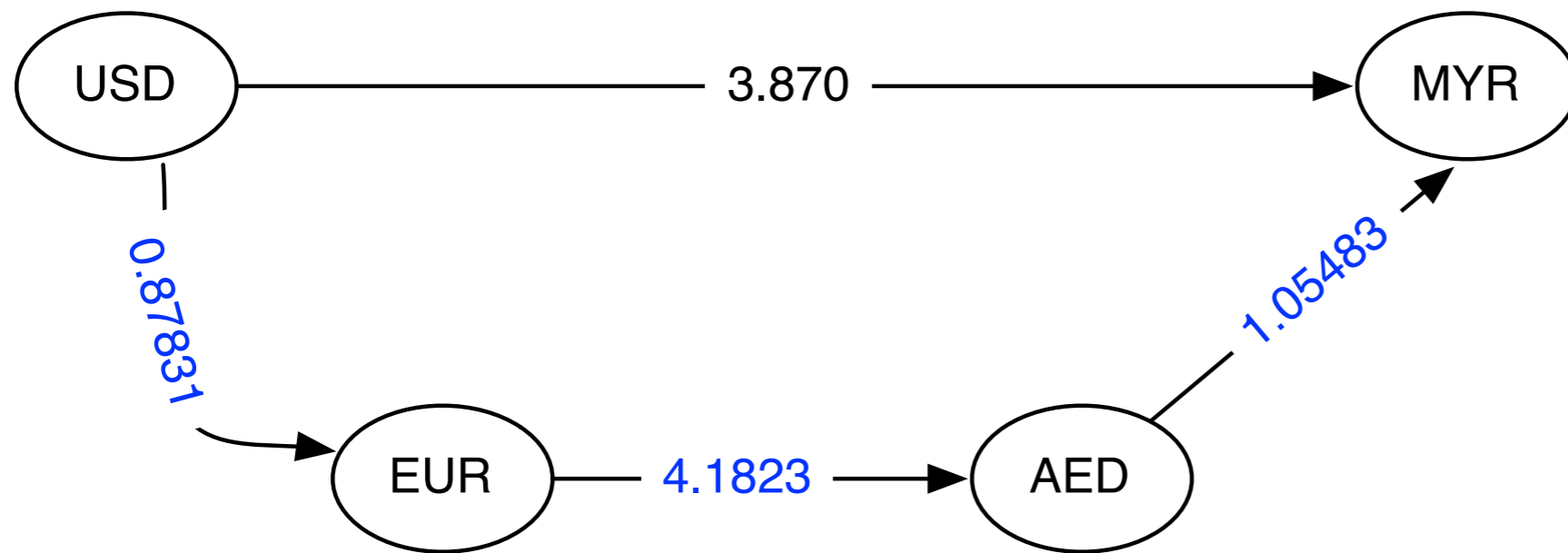
Currency code ▲▼	Currency name ▲▼	Units per EUR	EUR per Unit
USD	US Dollar	1.1386632306	0.8762227907
EUR	Euro	1.0000000000	1.0000000000
GBP	British Pound	0.7921136388	1.2624451227
INR	Indian Rupee	75.3658843112	0.0132888030
AUD	Australian Dollar	1.4859581878	0.6729873514
CAD	Canadian Dollar	1.4796754127	0.6758238945
SGD	Singapore Dollar	1.5347639238	0.6515960060
CHF	Swiss Franc	1.0917416715	0.9159576012
MYR	Malaysian Ringgit	4.4140052400	0.2265516114
JPY	Japanese Yen	128.1388820287	0.0078040325
CNY	Chinese Yuan Renminbi	7.3411003512	0.1362193612
NZD	New Zealand Dollar	1.8484648003	0.6065250248
THB	Thai Baht	39.9627318192	0.0250233143
HUF	Hungarian Forint	313.9042436792	0.0031856849
AED	Emirati Dirham	4.1823100458	0.2391023117

Mid-market rates as of 2016-03-31 17:39 UTC

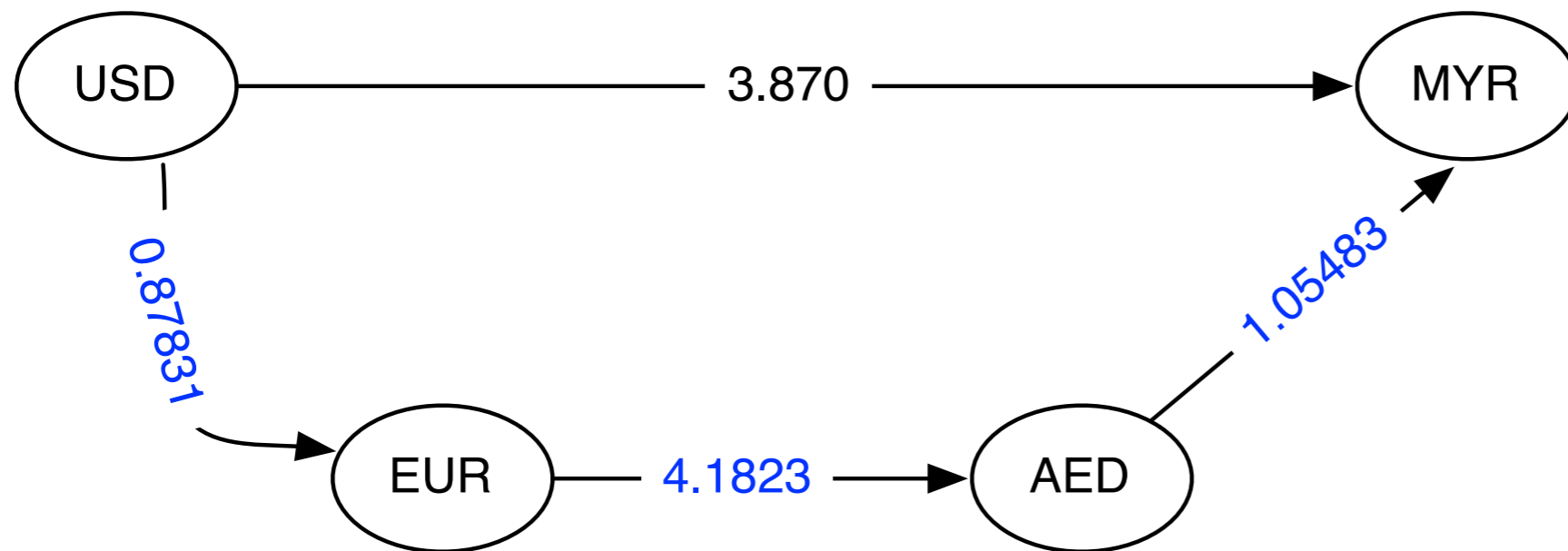
Currency code ▲▼	Currency name ▲▼	Units per AED	AED per Unit
USD	US Dollar	0.2722570108	3.6730000000
EUR	Euro	0.2391289974	4.1815433177
GBP	British Pound	0.1893997890	5.2798369266
INR	Indian Rupee	18.0207422309	0.0554918100
AUD	Australian Dollar	0.3552895418	2.8145257760
CAD	Canadian Dollar	0.3538334124	2.8261987234
SGD	Singapore Dollar	0.3669652245	2.7250538559
CHF	Swiss Franc	0.2610688193	3.8304105746
MYR	Malaysian Ringgit	1.0548325819	0.9480177576
JPY	Japanese Yen	30.6399242607	0.0328371564
CNY	Chinese Yuan Renminbi	1.7555154332	0.5696332719
NZD	New Zealand Dollar	0.3941937299	2.5355237088
THB	Thai Baht	9.5553789460	0.1046530970
HUF	Hungarian Forint	75.0637936939	0.0133220019
AED	Emirati Dirham	1.0000000000	1.0000000000



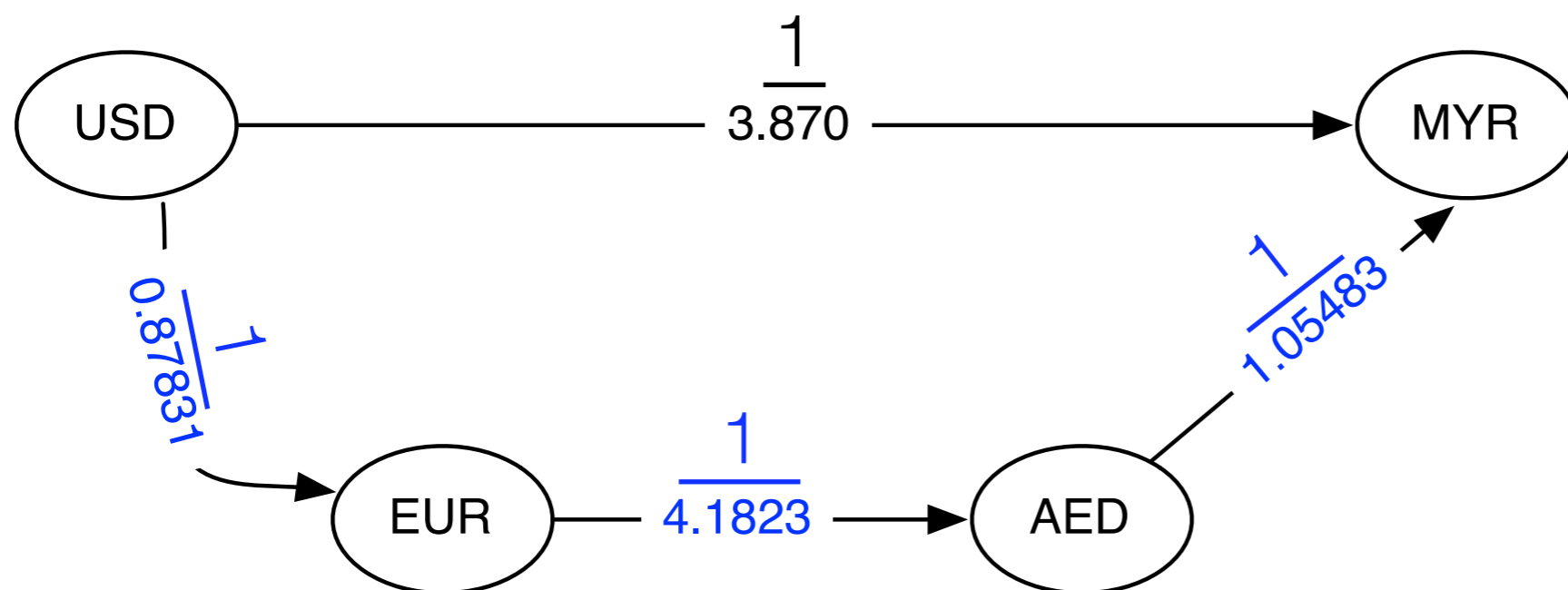




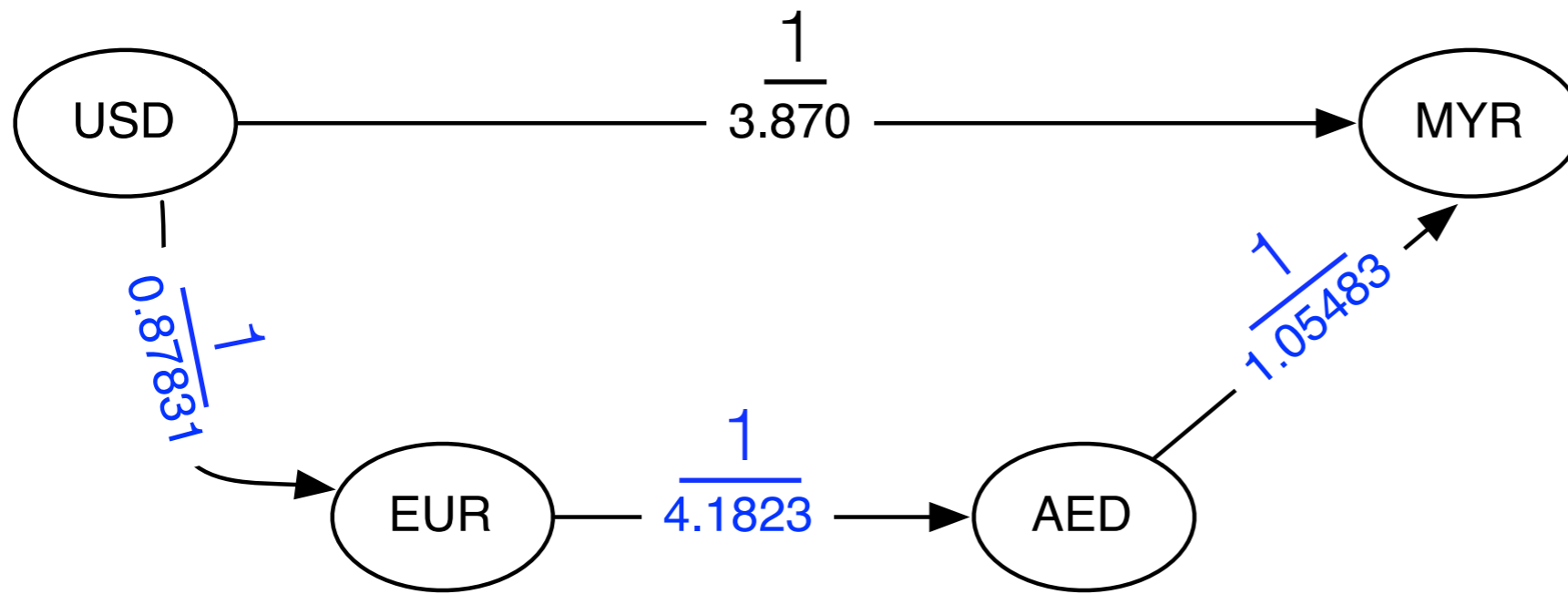
Trying to find
Max weight
(mult) Paths



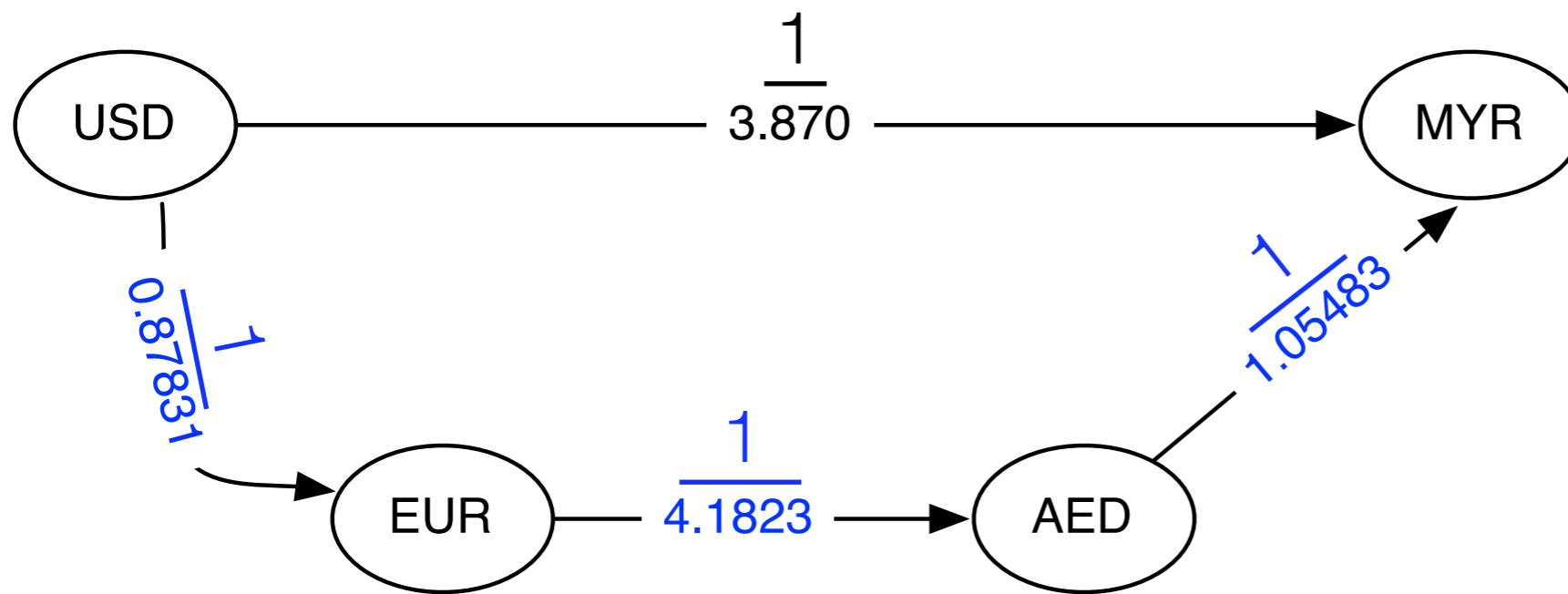
Trying to find
Max weight
(mult) Paths



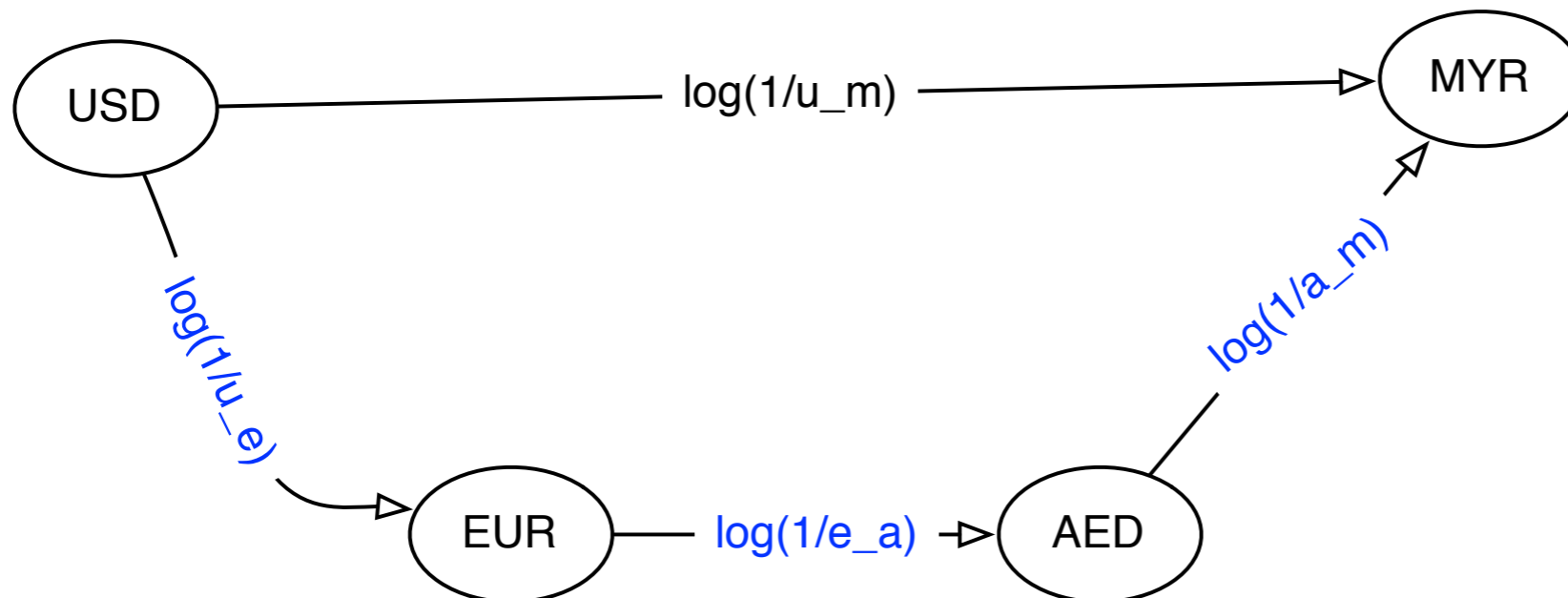
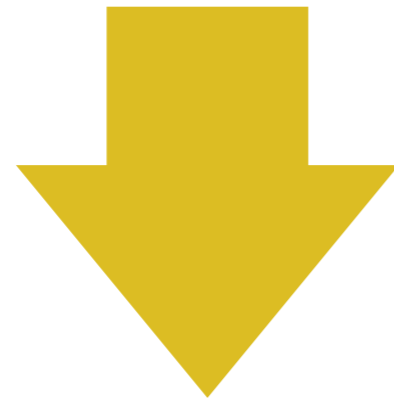
Trying to find
MIN weight
(mult) Paths

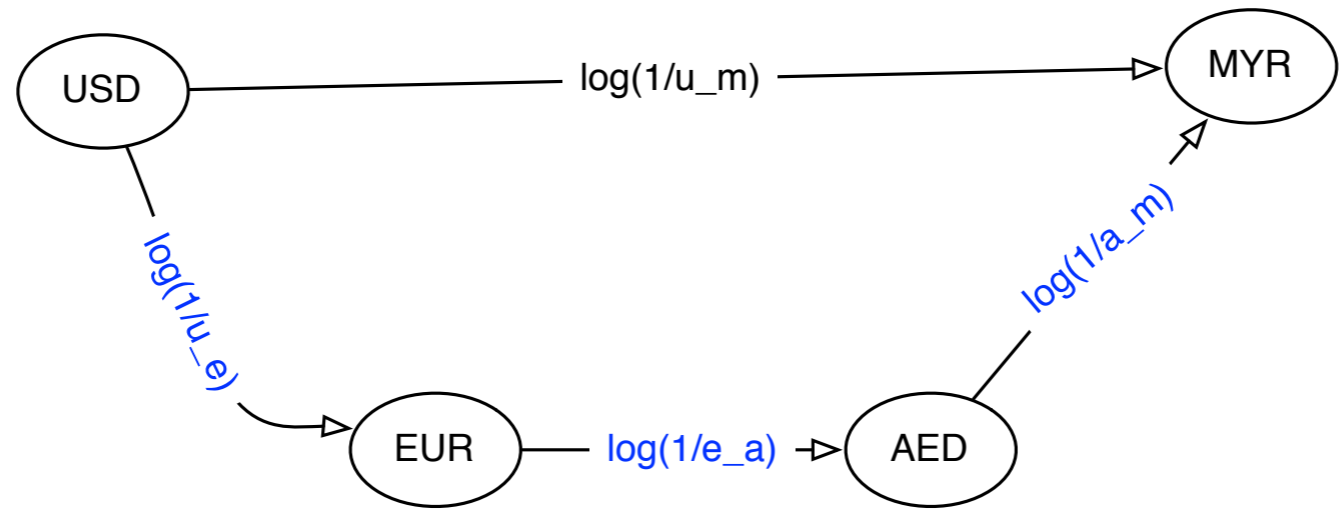


Trying to find
MIN weight
(mult) Paths



Trying to find
MIN weight
 (mult) Paths





SSSP(G, s)

SHORT $_{i,v} =$

SSSP(G, s)

$$\text{SHORT}_{i,v} = \begin{cases} \infty & i = 0 \\ 0 & v = s \\ \min_{x \in V} \left\{ \begin{array}{l} \text{SHORT}_{i-1,v} \\ \text{SHORT}_{i-1,x} + w(x,v) \end{array} \right\} & \end{cases}$$

max len of a simple path:

Bellman-Ford(G, s)

BELLMAN-FORD(G, s)

1 $\text{SHORT}_{0,s} \leftarrow 0$

2 $\forall v \in V - \{s\}, \text{SHORT}_{0,v} \leftarrow \infty$

3 **for** $i = 1, \dots, V - 1$

4 **do for** each $v \in V - \{s\}$

5 **do** $\text{SHORT}_{i,v} = \min_{x \in \text{Adj}(v)} \left\{ \begin{array}{l} \text{SHORT}_{i-1,v} \\ w(x, v) + \text{SHORT}_{i-1,x} \end{array} \right\}$

BELLMAN-FORD(G, s)

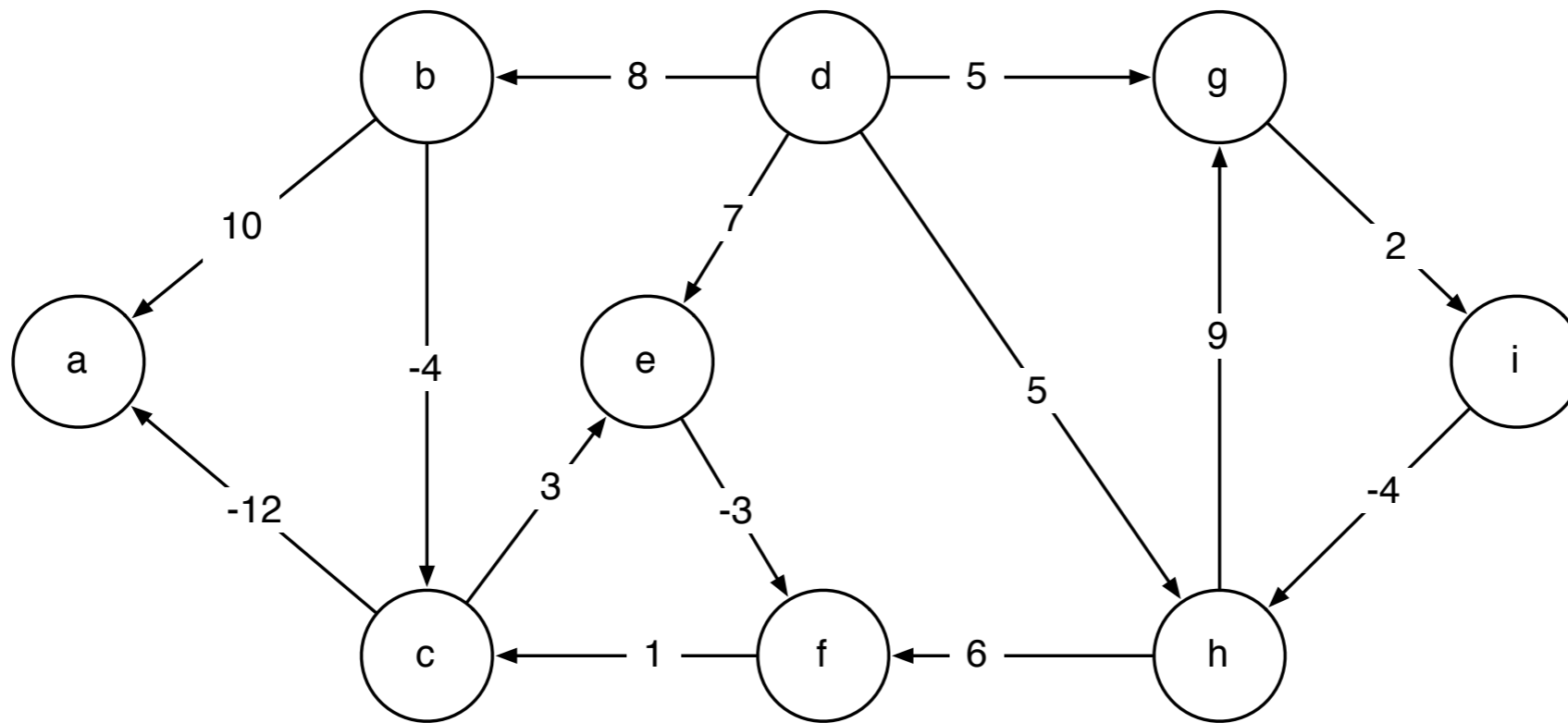
1 $\text{SHORT}_{0,s} \leftarrow 0$

2 $\forall v \in V - \{s\}, \text{SHORT}_{0,v} \leftarrow \infty$

3 **for** $i = 1, \dots, V - 1$

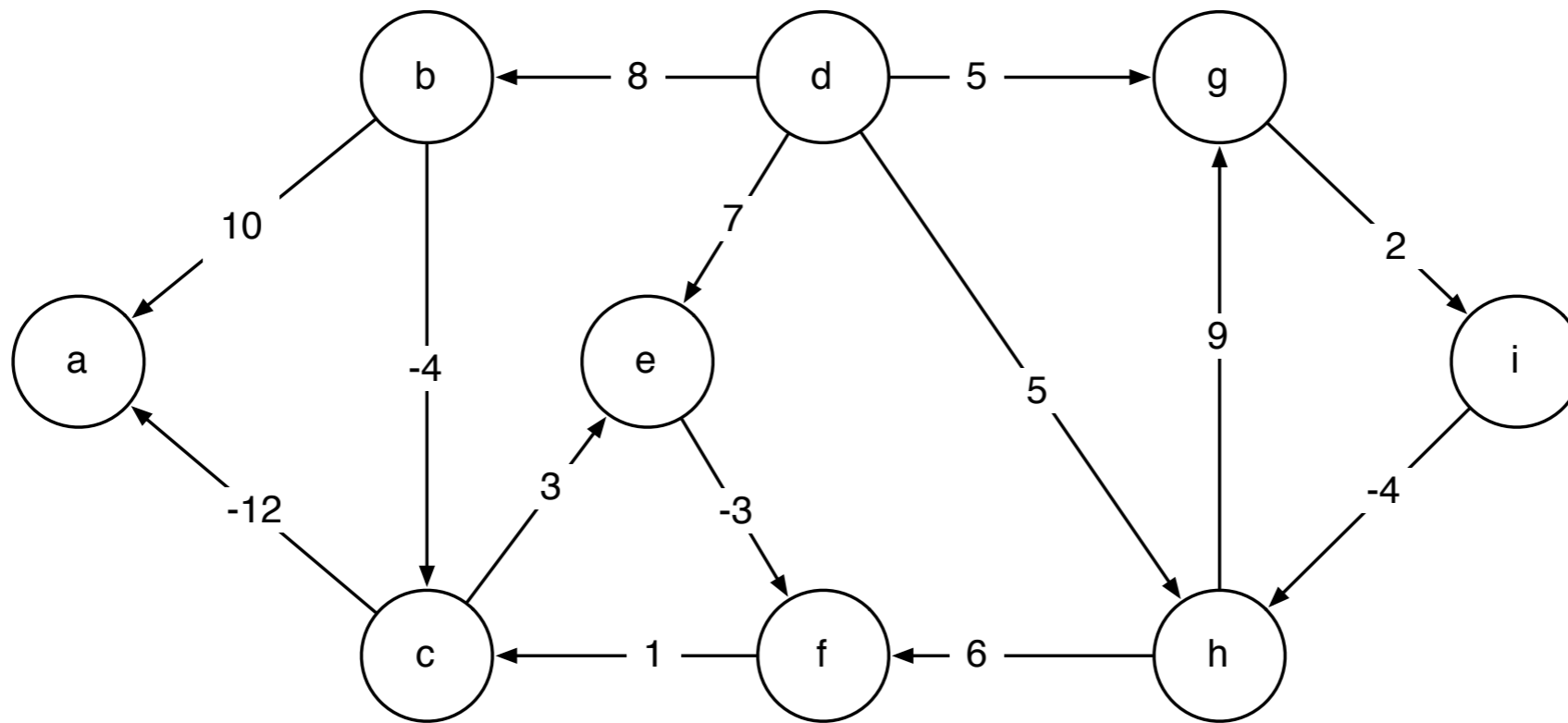
4 **do for** each $e = (x, y) \in E$

5 **do** $\text{SHORT}_{i,y} = \min \left\{ \begin{array}{l} \text{SHORT}_{i-1,y} \\ \text{SHORT}_{i,y} \\ w(x, y) + \text{SHORT}_{i-1,x} \end{array} \right\}$



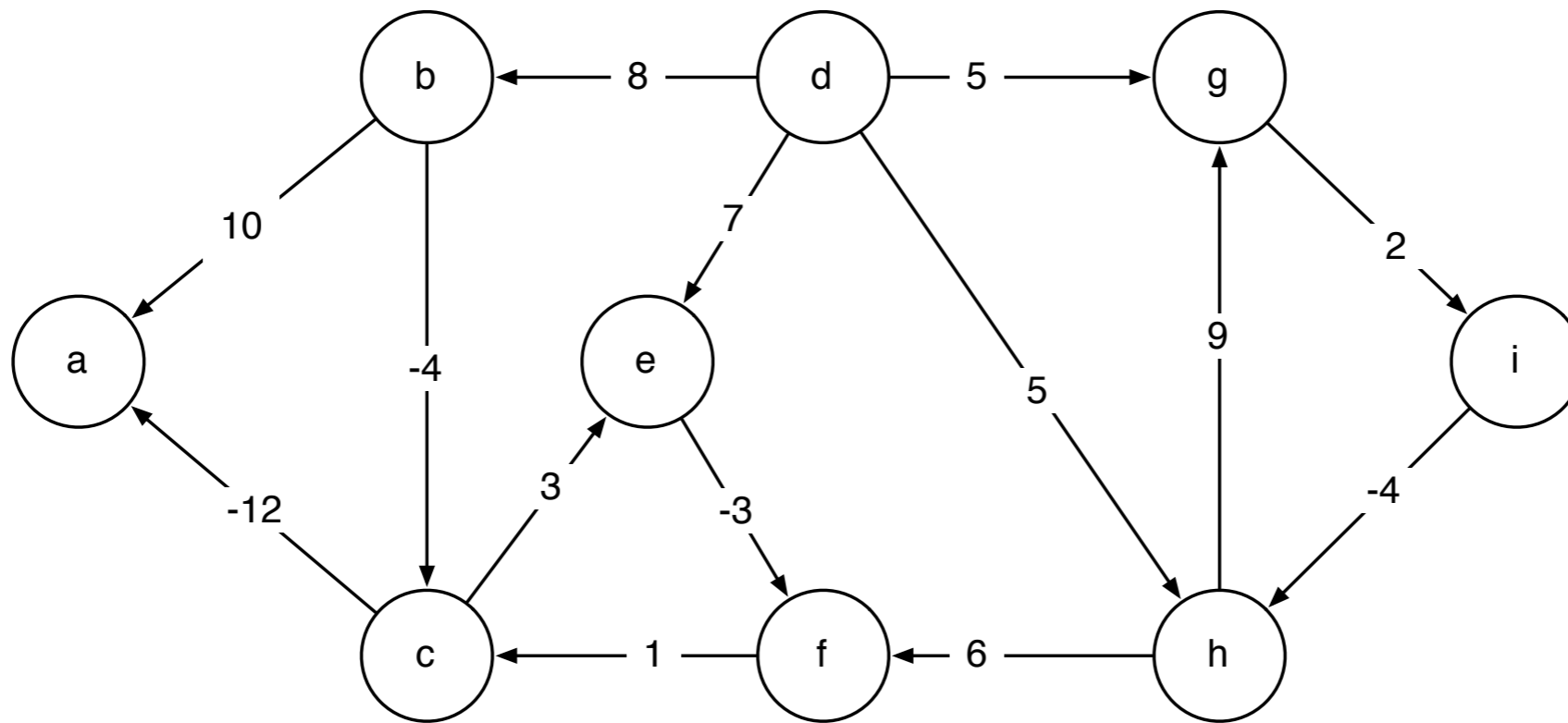
$$\text{SHORT}_{i,v} = \begin{cases} \infty & i = 0 \\ 0 & v = s \\ \min_{x \in V} \left\{ \begin{array}{l} \text{SHORT}_{i-1,v} \\ \text{SHORT}_{i-1,x} + w(x,v) \end{array} \right\} & \end{cases}$$

	8						
0	0						
	7						
	5						
	5						



$$\text{SHORT}_{i,v} = \begin{cases} \infty & i = 0 \\ 0 & v = s \\ \min_{x \in V} \left\{ \begin{array}{l} \text{SHORT}_{i-1,v} \\ \text{SHORT}_{i-1,x} + w(x,v) \end{array} \right\} & \end{cases}$$

		18					
	8	8					
		4					
0	0	0					
	7	7					
		4					
	5	5					
	5	5					
		7					



$$\text{SHORT}_{i,v} = \begin{cases} \infty & i = 0 \\ 0 & v = s \\ \min_{x \in V} \left\{ \begin{array}{l} \text{SHORT}_{i-1,v} \\ \text{SHORT}_{i-1,x} + w(x,v) \end{array} \right\} & \end{cases}$$

		18	-8				
	8	8	8				
		4	4				
0	0	0	0				
	7	7	7				
		4	4				
	5	5	5				
	5	5	3				
		7	7				

Optimization

BELLMAN-FORD(G, s)

```
1  SHORT0,s ← 0
2  ∀v ∈ V − {s}, SHORT0,v ← ∞
3  for i = 1, ..., V − 1
4      do for each e = (x, y) ∈ E
5          do SHORTi,y = min {
```

$$\left. \begin{array}{l} \text{SHORT}_{i-1,y} \\ \text{SHORT}_{i,y} \\ w(x, y) + \text{SHORT}_{i-1,x} \end{array} \right\}$$

BELLMAN-FORD(G, s)

```
1  ds ← 0
2  ∀v ∈ V − {s}, dv ← ∞
3  for i = 1, ..., V − 1
4      do for each e = (x, y) ∈ E
5          do dy ← min { dy, w(x, y) + dx }
```

running time

BELLMAN-FORD(G, s)

1 $d_s \leftarrow 0$

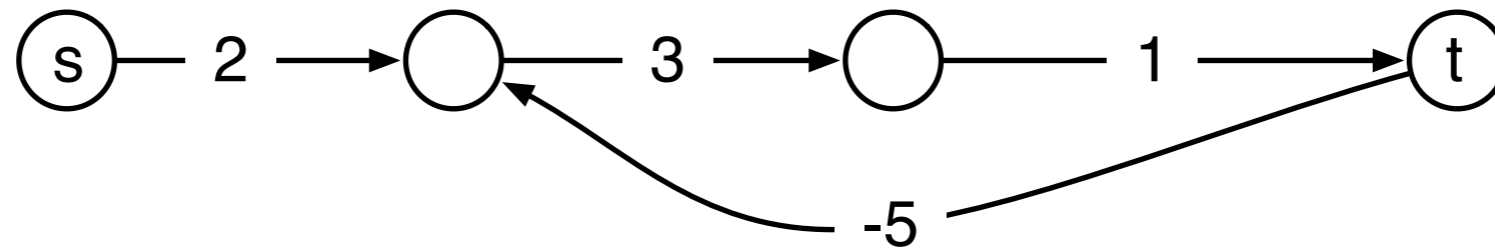
2 $\forall v \in V - \{s\}, d_v \leftarrow \infty$

3 **for** $i = 1, \dots, V - 1$

4 **do for** each $e = (x, y) \in E$

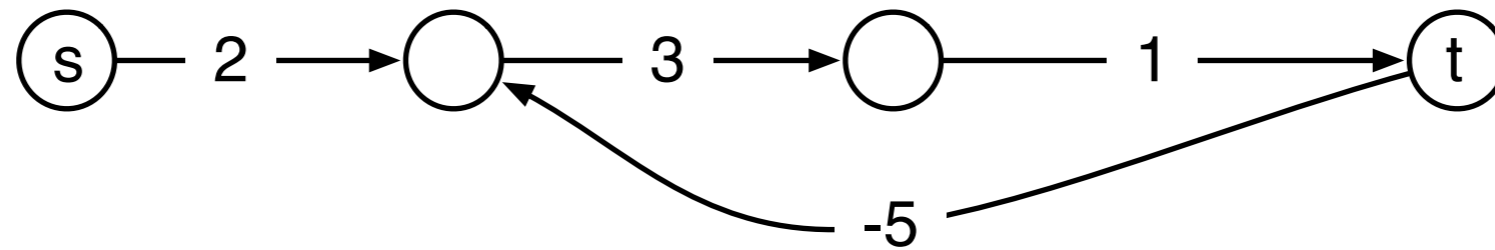
5 **do** $d_y \leftarrow \min \{ d_y, w(x, y) + d_x \}$

negative cycles?



s	0				
a					
b					
t					

negative cycles?



s	0	0	0	0
a	2	2	2	1
b		5	5	5
t			6	6