

Resit exam questions (2021-07-15)

Exam protocol

- Choose language es/ca/en
- We are recording now, the recording will stay in the platform with access only to me, me unless the university authorities request it for some reason
- Please place your mobile in airplane mode (unless you're using it for communicating with me)
- Please briefly show me the room where you are giving your exam
- Please briefly share with me ("present") your entire computer screen
- We will start with a topic you think you've studied more, then we will go back to slide #3 and roll the dice to determine each question; if we land on a question you've already answered or a non-question slide, I ask you the next one; if we get to the end we restart
- I'll ask you questions for 20 minutes starting now – pick the initial topic please

TT01 Complex networks

TT02. Complex networks

What is a complex system?

What is a complex network?

TT04. Graph theory basics

What is a **digraph**?

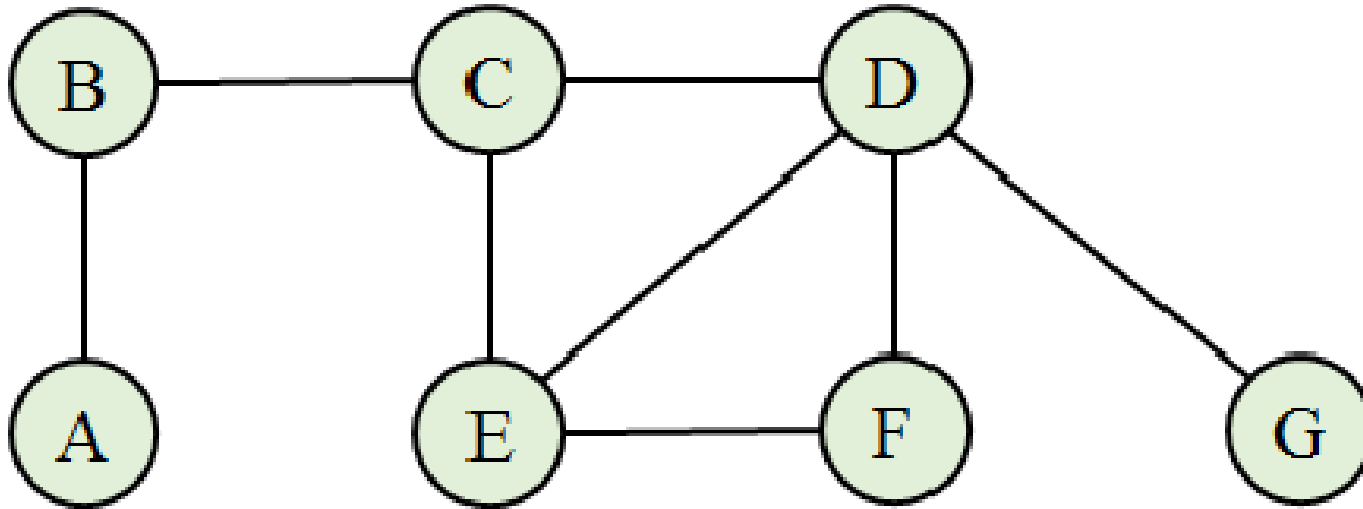
TT04. Graph theory basics

Draw the graph corresponding to this adjacency matrix

	0	1	2	3	4
0	0	2	3	0	0
1	2	0	15	2	0
2	3	15	0	0	13
3	0	2	0	0	9
4	0	0	13	9	0

TT04. Graph theory basics

Write the adjacency matrix of this network:



TT05. Sparsity and connectivity

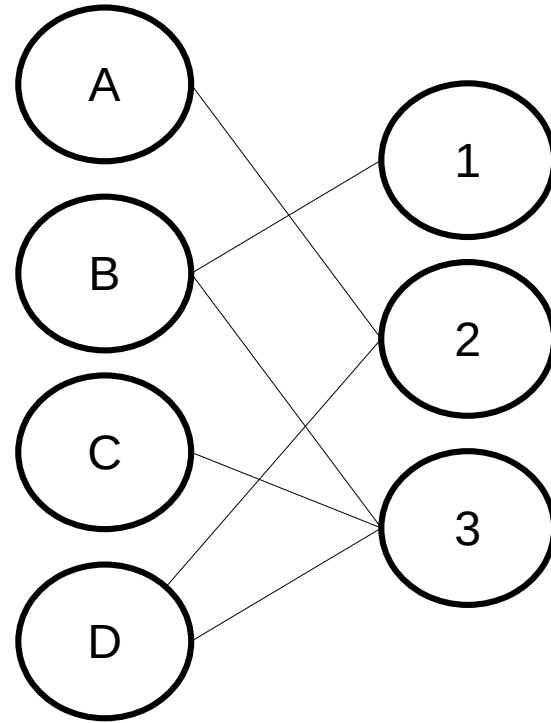
What is a bi-partite graph?

TT05. Sparsity and connectivity

Why do we say most real networks are sparse?

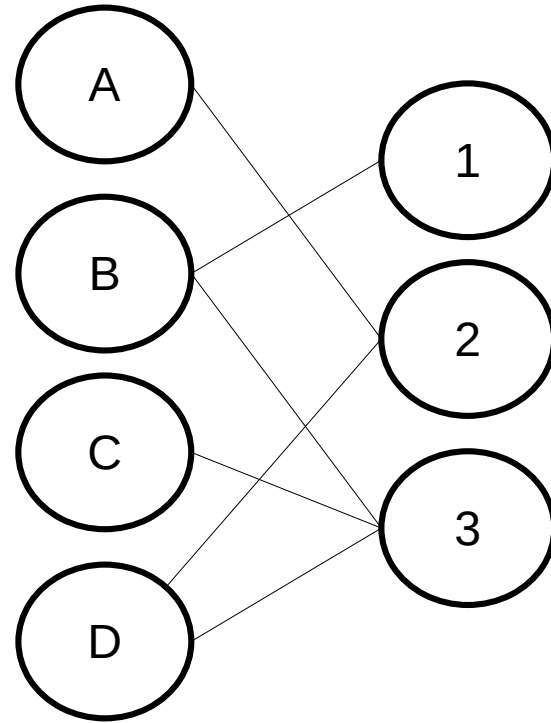
TT05. Sparsity and connectivity

Draw the left- and right-projection of this bipartite graph



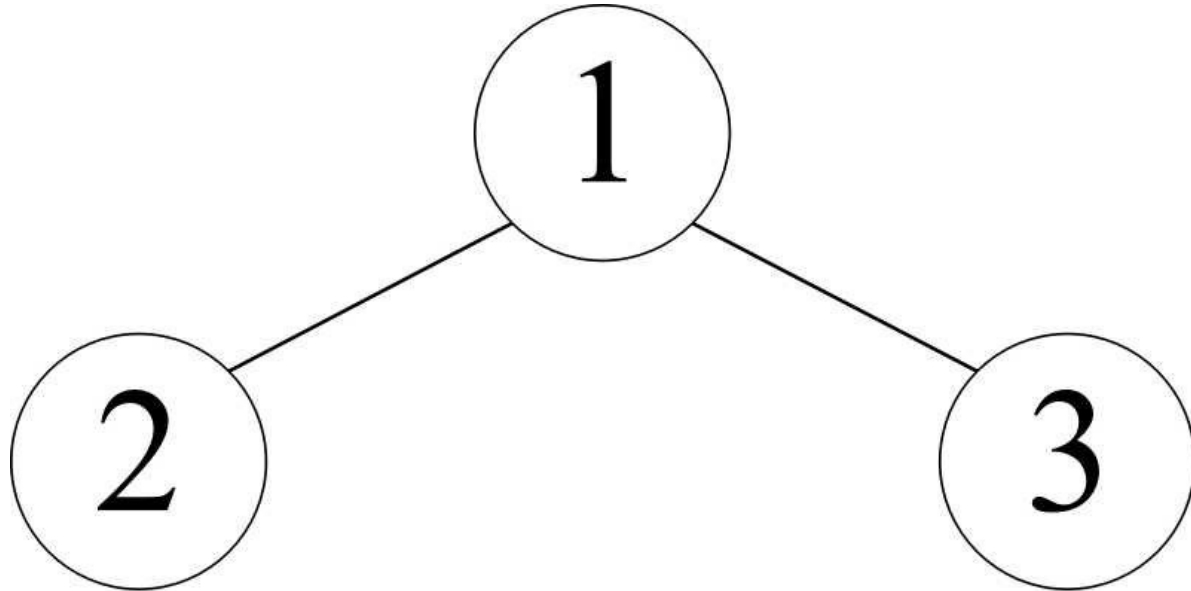
TT05. Sparsity and connectivity

What is the **diameter** of this graph?



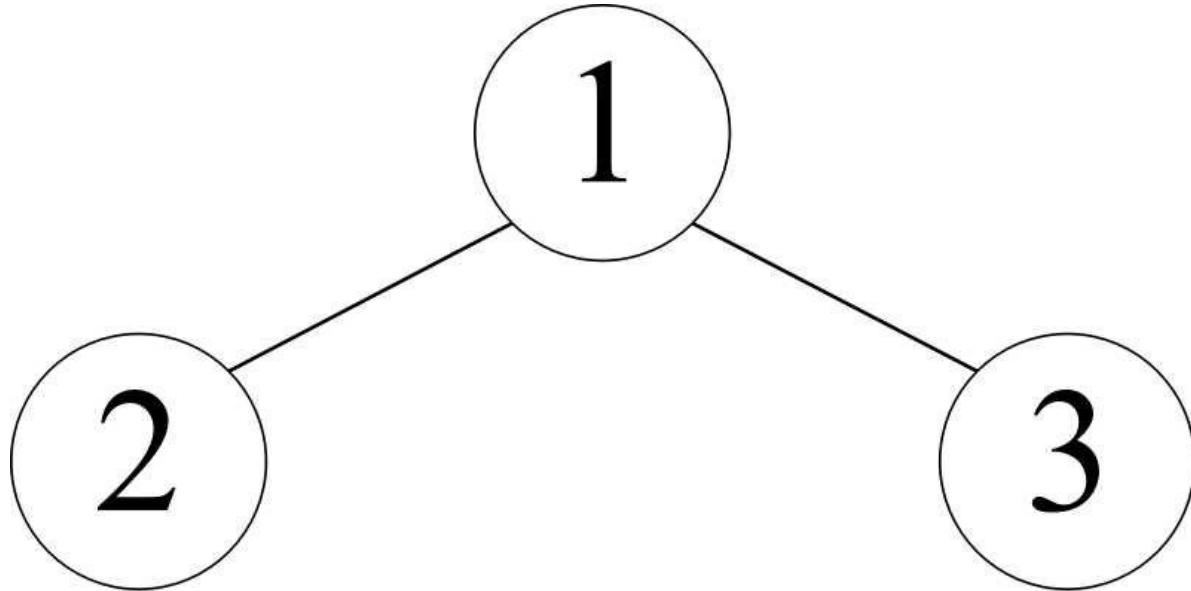
TT05. Sparsity and connectivity

What is the average distance in this graph?



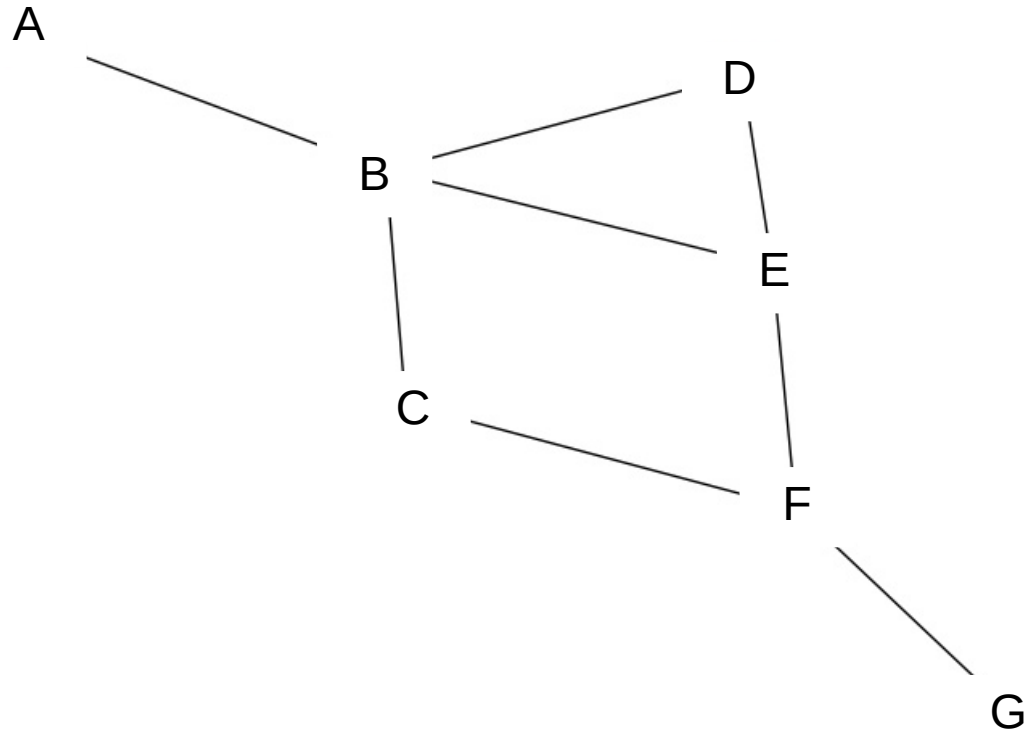
TT05. Sparsity and connectivity

What is the sparsity of this graph L / L_{max} ?



TT06. Clustering coefficient

Compute the **local clustering coefficient** of each node in this graph



TT06. Clustering coefficient

What is a the (global) clustering coefficient of a graph?

TT07. Random networks

Indicate what input parameters are needed and how one creates a random (ER) graph

TT07. Random networks

What is the maximum degree in an ER graph of N nodes and edge probability p ?

TT07. Random networks

What is the expected number of links in an ER graph of N nodes and edge probability p ?

TT07. Random networks

What probability distribution follows the degree in an ER network?

TT07. Random networks

If an ER graph has average degree $\langle k \rangle$ and N nodes, what is its linking probability p ?

TT08. Properties of rand. networks

Consider the average degree in a network $\langle k \rangle$

What regime is the network in in the following cases? Explain what each regime means:

$$\langle k \rangle < 1$$

$$\langle k \rangle > 1$$

$$\langle k \rangle > \log N$$

TT08. Properties of rand. networks

What is the average distance between two nodes
in an ER network of
N nodes and average degree $\langle k \rangle$?

TT08. Properties of rand. networks

What is the minimum average degree *necessary* for a graph to be connected?

TT08. Properties of rand. networks

What is the expected clustering coefficient of a node in an ER network?

TT09. Scale-free networks

What does it mean to be scale-free in a scale-free network?

TT09. Scale-free networks

Which **probability distribution** follows the degree of nodes in a scale-free network?

TT09. Scale-free networks

Which networks do not exhibit a scale-free property?

TT10. Distances in scale-free networks

What is the difference in the average distance of networks having $2 < \gamma < 3$ and networks having $\gamma > 3$?

TT10. Distances in scale-free networks

What is the **friendship paradox**?

TT11 Preferential attachment

Explain the Uniform Random Attachment model and its differences with the BA model

TT11 Preferential attachment

What are the **input parameters** to the **BA** network model?

TT11 Preferential attachment

Describe two of the steps requiring randomization of the preferential attachment generation algorithm

TT12 Deg. preferential attachment

Which degree distribution have graphs generated using the BA model?

TT12 Deg. preferential attachment

Which nodes have larger degree in a BA graph, those who are created early or those who are created late? Why?

TT12 Deg. preferential attachment

What is the power-law exponent γ of the degree distribution in a graph generated using the BA model?

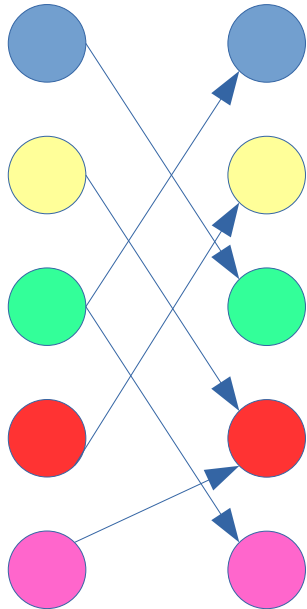
Can this be changed within the BA model?

TT12 Deg. preferential attachment

Describe how to create a graph
using the **copy model**

TT14 Hubs and authorities

Execute some steps of HITS on this graph

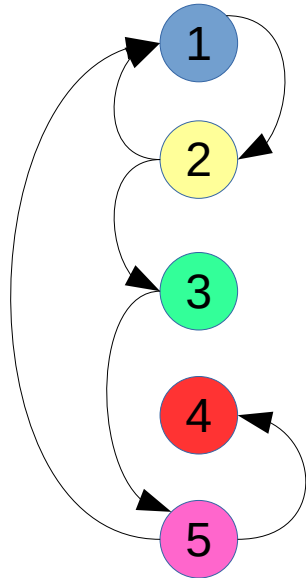


$\hat{H}(1)$	A(1)	$\hat{A}(1)$	H(2)	$\hat{H}(2)$	A(2)	$\hat{A}(2)$
1						
1						
1						
1						
1						

TT15 PageRank

Execute some steps of **Simplified PageRank**

underlined italics = normalized value



P(1)	P(2)	<u>P(2)</u>	P(3)	<u>P(3)</u>	P(4)	<u>P(4)</u>
1						
1						
1						
1						
1						

TT15 PageRank

Why do we use PageRank
instead of Simplified PageRank?

What is the problem with Simplified PageRank?

TT15 PageRank

In terms of the adjacency matrix of a graph, what is the PageRank of the nodes?

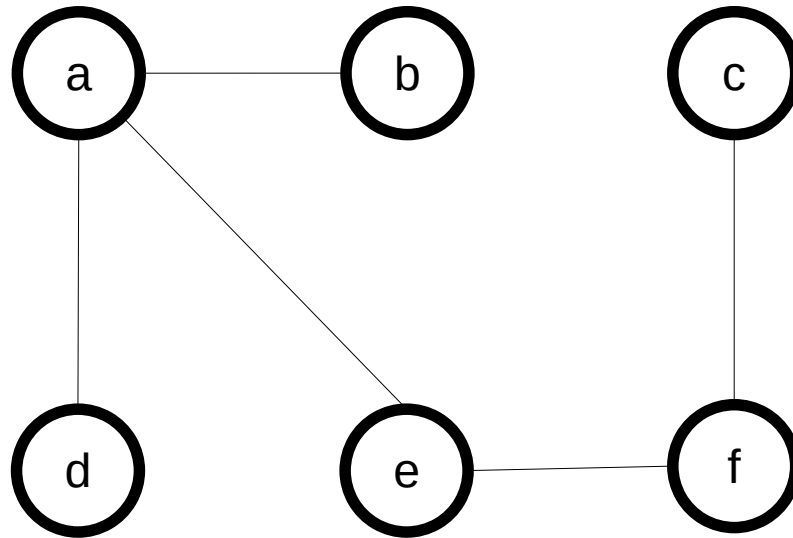
TT17 Closeness

What is the closeness of a node?

What is the harmonic closeness of a node?

TT17 Closeness

What is the closeness of one node in this graph?

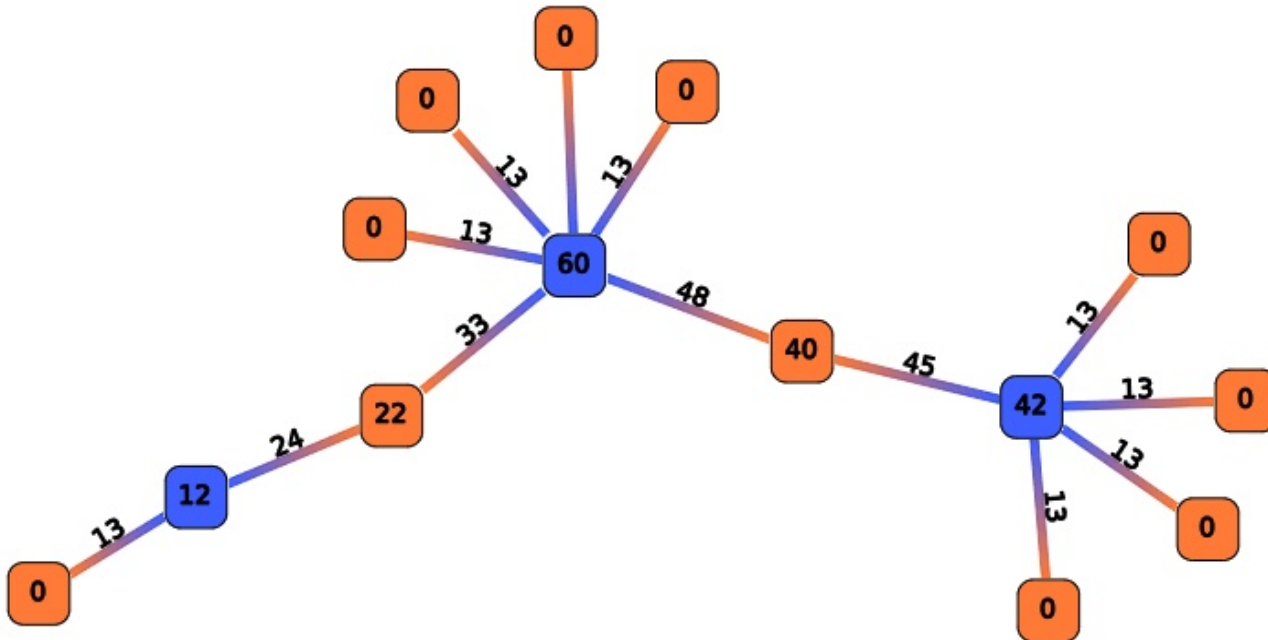


TT18 Betweenness

What is the betweenness of a **node**?

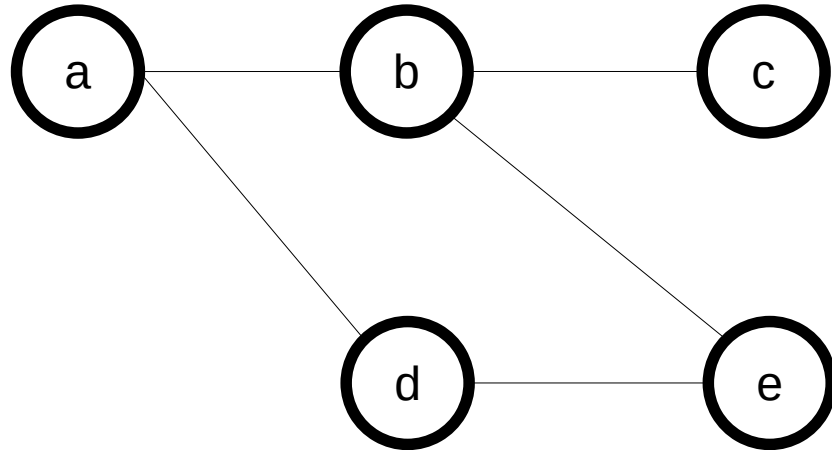
TT18 Betweenness

Why is the betweenness of the blue node on the left 12?



TT18 Betweenness

Compute betweenness using the Brandes-Newman algorithm



TT18 Betweenness

Sketch a graph of N nodes in which a node, which you should mark with an asterisk (*) should have betweenness approximately equal to N and closeness approximately $1/N$ for large N . Explain.

TT19 Community structure

Give an example of a real-world network having two communities, and one having multiple communities

TT20 Network flows

What is the max-flow problem?

TT20 Network flows

What is the min-cut problem?

TT10 Network flows

Why do we say max flow and min cut are equivalent problems?

TT10 Network flows

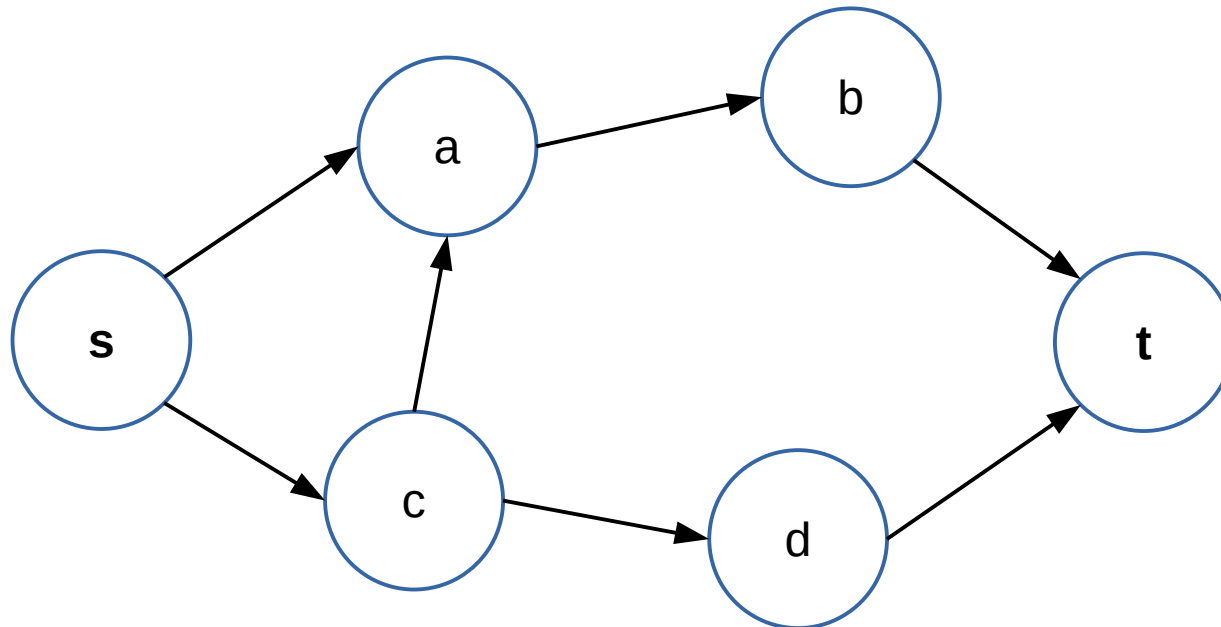
Write the formulation of max flow
as a linear system

TT10 Network flows

Write the formulation of min cut
as a linear system

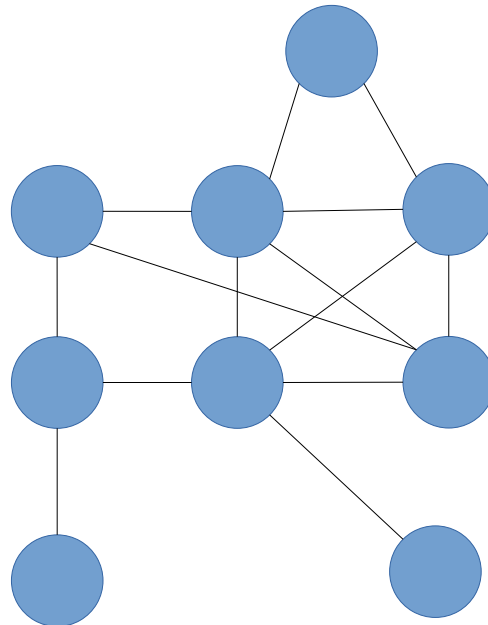
TT20 Network flows

Use the randomized algorithm we saw in class to find the min cut of this graph



TT22 Dense sub-graphs

Perform a k-core decomposition of this graph



TT22 Dense sub-graphs

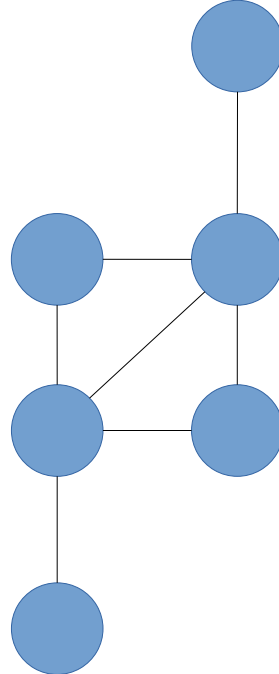
Describe two **density definitions** that are commonly used

TT22 Dense sub-graphs

What is the density definition used in Golderg's construction?

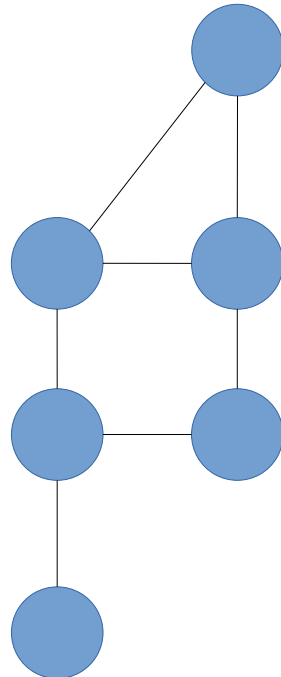
TT22 Dense sub-graphs

Draw Goldberg's construction on this graph for target density $5/2 = 2.5$



TT22 Dense sub-graphs

Perform Charikar's algorithm on this graph;
remember we measure density as $|E|/|V|$



TT24 Spreading phenomena

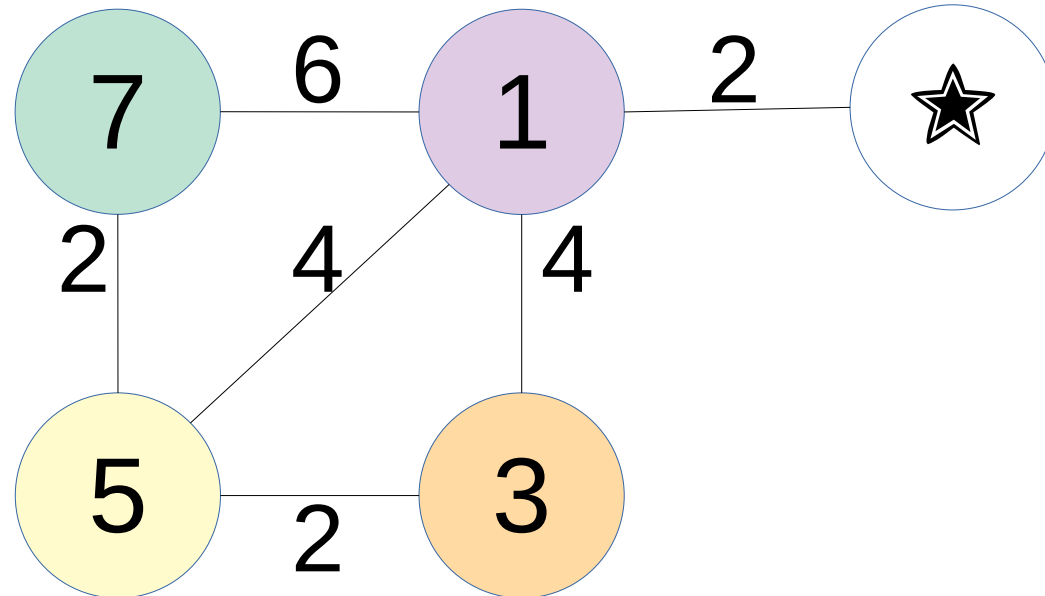
Describe the linear threshold propagation model

TT24 Spreading phenomena

Describe the independent cascade propagation model

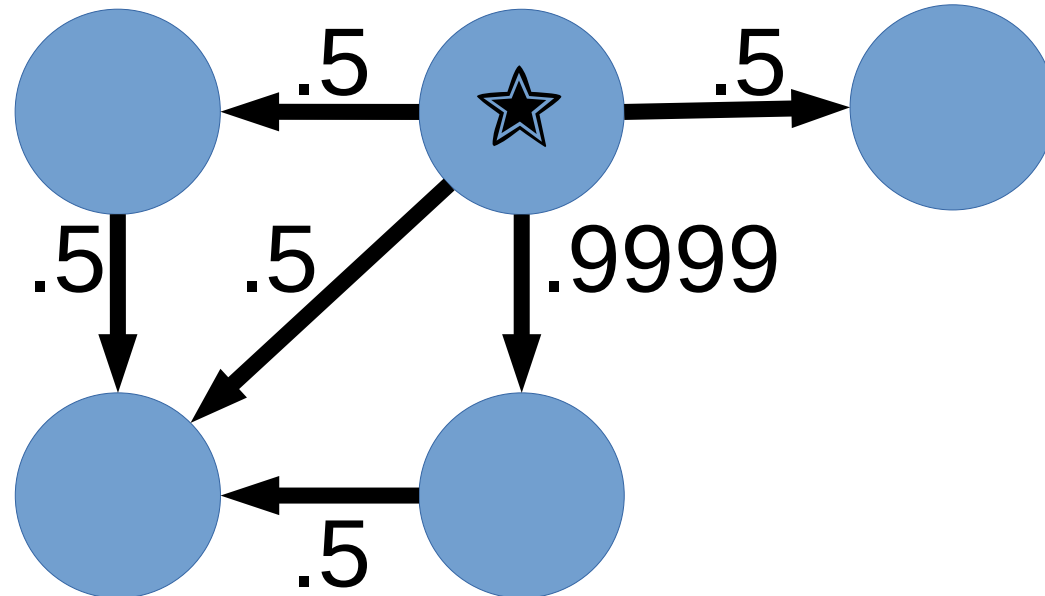
TT24 Spreading phenomena

Run the **linear threshold** model on this graph starting from the node marked ★



TT24 Spreading phenomena

Run the independent cascade model on this graph starting from the node marked \star



TT26 Epidemics

Indicate what the
basic reproductive number R_0 means

Indicate its formula in a branching process

TT26 Epidemics

Describe the SI model

What fraction of the nodes are infected at the end of a SI infection process?

TT26 Epidemics

Describe the SIS model

Does the SIS model reach a steady state?
How is this steady state called?

TT26 Epidemics

Describe the SIR model

What fraction of the nodes are **recovered** at the end of a SIR infection process?

TT26 Epidemics

Describe the meaning of different variables in the following equations, which describe changes in the number of infected under a SIR process using conventional notation:

$$\frac{di(t)}{dt} = \beta \langle k \rangle i(t)(1 - r(t) - i(t)) - \mu i(t)$$

TT27 Epidemics on graphs

What is the characteristic time of an infection?

TT27 Epidemics on graphs

What is the characteristic time as N grows in a scale-free network with $\gamma < 3$?