FINAL EXAMINATION
Networked Life (MKSE 112)
December 14, 2012
Prof. Michael Kearns

This is a closed-book exam. You should have no material on your desk other than the exam itself and a pencil or pen. If you run out of room on a page, you may use the back, but be sure to indicate you have done so.

Name: ____

Penn ID: ____

Problem 1: ________/10

Problem 2: ________/15

Problem 3: ________/15

Problem 4: ________/15

Problem 5: ________/15

Problem 6: ________/10

Problem 7: ________/20

TOTAL: _________/100

Problem 1 (10 points) For each of the following statements, simply write "TRUE" or "FALSE".

a. Wealth variation at equilibrium in the trading model we studied is characterized by whether the network is connected or not.

b. The distance between two vertices is defined as the length of the shortest path between them.

c. The assigned reading "The Scaling Laws of Human Travel" relies on data about the geographic distances between Facebook friends.

d. Different types of Internet services (e.g. Skype, Facebook, web browsing) have specialized types of packets associated with each of them.

e. The behavioral experiments on biased voting established that a small but well-connected minority could systematically control the collective outcome.

f. The Columbia Small Worlds experiment reverses almost all of the findings of Travers and Milgram.

g. Schelling's segregation model was designed to demonstrate that segregation only arises when individuals have extreme preferences regarding their neighbors.

h. The "traceroute" program we demonstrated in class outputs the sequence of routers encountered as a packet travels through the Internet.

i. Even at low edge density, a bipartite version of the Erdos-Renyi model is likely to generate networks containing a perfect matching.

j. A pure Nash equilibrium always exists if the players have only two actions available.

Problem 2 (15 points) Define a vertex u in a network to be *crucial* if there exist two other vertices v and w such that there is a path from v to w that goes through u, but if u is deleted from the network, there is no path from v to w.

a. For any given number of vertices N, describe what network structure results in the greatest number of crucial vertices.

b. Draw an example of a network in which there are no crucial vertices.

c. Is it possible to have networks in which every vertex is crucial? Why or why not?

Problem 3 (15 points) Suppose you use a high-level application like Skype to initiate a call, or an email client to send an email. In as much detail as you are able, describe the process by which packets are generated and travel through the Internet in response. Topics to include are: what the packets contain, how they travel and are forwarded through the Internet, the series of devices and types of organizations the packets encounter, and how the Skype call or email is rendered on the receiving end. Greater detail will earn greater credit.

Problem 4 (15 points) Write a brief essay in which you compare and contrast the following three problems:

- navigation in social networks (Travers&Milgram, Columbia Small Worlds, Kleinberg's model)
- packet routing in the Internet (both routing table-based, and "selfish"/source routing)
- driving or commuting over a network of physical roadways

You should discuss the ways in which these problems are similar, and different, and support your claims with course readings and lectures.

Problem 5 (15 points) In lecture we briefly discussed the example of email spam as a problem with both technological approaches (spam filters, email blacklists and whitelists) and economic approaches (micropayments for email; that is, very tiny payments for sending email that would be negligible for ordinary users but prohibitive for professional spammers). Give another example, *different from any given in class*, of a problem with both technological and economic solutions. Identify what the proposed solution(s) are in each case.

Problem 6 (10 points)

a. Draw the simplest network you can of 15 vertices in which the diameter is at least 5, the clustering coefficient is much higher than the edge density, and the degree distribution is *not* heavy-tailed.

b. On the same network diagram above, using dashed instead of solid lines, clearly add a couple of edges so that the diameter will now be less than 4, while the clustering coefficient and degree distribution do not change much.

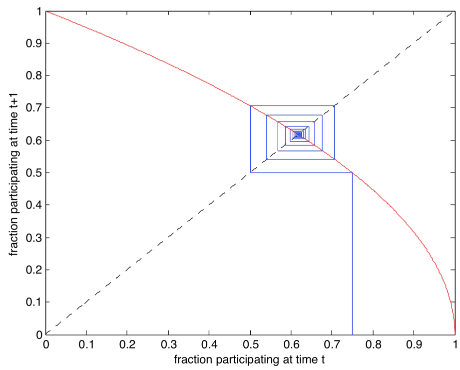

Figure 1

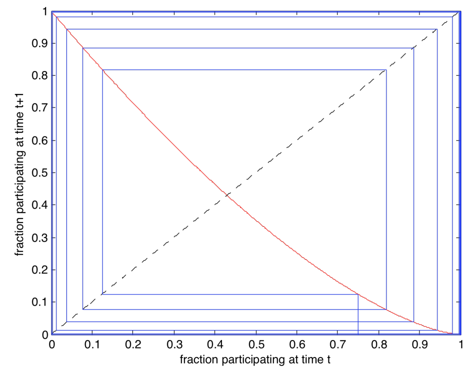

Figure 2

Problem 7 (20 points) The two figures above show, in the red curves, models for the amount of collective participation in some activity at time t+1 (y axis) as a function of the amount of participation at time t (x axis). Answer the following questions *for each of the two figures.* You may clearly annotate the diagrams if it will help clarify your answers.

a. How many equilibrium points are there, and are they stable or unstable?

b. What will be the limiting behavior of the population if we repeat the process indefinitely (i.e. let t go to infinity?)

c. If in part b. you answered differently for the two figures, discuss why you think the limiting behavior is different; and if you answered the same for the two figures, discuss why you think the limiting behavior is the same.