CQ 1

**What is the dilemma of the Prisoners' Dilemma and what does this illustrate more generally about Nash equilibria?**

The dilemma is that while both prisoner's would benefit from both cooperating, the rational decision individually is to defect, which is globally suboptimal. It illustrates that if it is common knowledge that if every actor will always behave rationally, every agent will make a "locally" optimal choice based on that assumption, which does not necessarily yield an global optimum if everyone had agreed on a certain action beforehand, which could be enforced. This can be related to the price of anarchy explained in lecture.

**How can you argue that there is no pure-strategy Nash Equilibrium in the Matching Pennies game?**

There is no pure-strategy Nash equilibrium because if we fix the action of Player 1, and we pick the action of Player 2 rationally based on the action of Player 1. From Player 1's perspective, he would wish to change his action, and so on. For any action profile, there is always a player whose utility function would increase by changing their individual action, which would make the other player strictly worse.

**Why must all actions in the support of a mixed strategy that is part of a Nash equilibrium have the same expected utility?**

If not all actions in the support of a mixed strategy that is part of a Nash equilibrium have the same expected utility, then there exists at least one action “*a”* in the support that has higher utility than another action “b”. That means there exists another strategy that does not contain “b” in the support, and thus has a higher expected utility. Thus, the actions in the support must all have the same expected utility.

**What distinguishes a correlated equilibrium from a Nash equilibrium? What’s an example of a correlated equilibrium you play in your everyday life?**

Every finite, simultaneous-move game has at least one correlated equilibrium, while not every game has a Nash equilibrium, such as Rock, Paper, Scissors. An example of a correlated equilibrium is the situation that occurs between two cars at a stop light. If none of the cars advance, they both obtain nothing. If both advance at the same time, they both lose because they crash, but if one advances and the other one does not, then one wins nothing and the other one has a positive reward. When the light signal “suggests” player 1 to go, he will go and the other ones will stop, and the same goes for the case where the light signal “suggests” player 2 to stop.

# CQ 2: BitTorrent

**What was the biggest problem with Gnutella? (1 sentence!)**

There was no incentive for a participant of the Gnutella network to provide uploads to other, which lead to free-ridining (i.e., using the newtork to download but never offering uploads).

**Explain, in one sentence, the main difference between Gnutella and BitTorrent with regard to incentive design.**

Structurally, BitTorrent relies on trackers to know the IP addresses of the peers in the swarm for a file, vs the completely unstructured Gnutella network that relies on message-passing. In Gnutella, due to the way its network is structured, the chance of a client interacting with each other again is low, which why people choose the Nash equilibrium of free riding, but BitTorrent, by forcing clients dealing with the same file to interact repeatedly by chunking the file into smaller pieces, turns the game into a repeated game, which is know to allow for long-term cooperation.

**Describe three ways in which the BitTorrent file sharing game does not exactly correspond to a repeated Prisoners' Dilemma.**

1. In the Prisoner's Dilemma, just two players are interacting with each other, and it is always the same two players, while in the BitTorrent system, many clients interact with each other at the same time, and the network is not a complete graph (i.e., no every client is interacting with every other client). Since repeated play will not always occur with the same clients, it might be a dominant strategy to screw over another client if you don't think you will need to rely on them in the future.

2. Unlike the Prisoner's Dilemma, which is symmetric, in the case of BitTorrent we cannot assume that every client has the same reward/cost per action, and that they have the same goals. This makes it so that there is no dominant strategy that maximizes the expected value against any other client, and one can actually achieve better overall performance by understanding the cost function of the other clients.

3. It is necessary to be able to "win" (get the complete file) to occasionally play a locally suboptimal move and reach out to a peer that is not currently in your top bandwidth providers, just for the sake of adding a new peer to the list and establishing a new connection that could lead to future collaboration.

**Describe three ways in which the BitTyrant unchoking strategy differs from the reference client.**

1. BitTyrant makes more effective use of the reference client's altruistic contributions providing uploads only to the clients with the highest likelihoods of providing good download speeds back, and only providing them with the bare minimum upload speed required to "unblock" them (i.e., to become one of their top "m" uploaders).

2. Due to its more effective and efficient use of network resources, a swarm of BitTyrant clients produces better performance conditioned on the same resources and upload speeds being allocated to the clients, but if users manually cap uploads at the point of diminishing returns to them personally, the whole system performance is worse than in a swarm with reference clients.

3. BitTyrant also attempts to push the limits of other clients by reducing their allocated bandwidth with time to test what the minimum bandwidth they should provide is to unblock the other client.