Theory of Mechanism Design - Assignment 1

Due: 24 August, 2017

1. A seller is selling an object to an agent whose value (type) for the object lies in the interval $I \equiv [0, 1]$. The seller uses an allocation rule $f : I \to [0, 1]$ and a payment rule $p : I \to \mathbb{R}$. Denote the mechanism (f, p) as M.

   Fix an $\epsilon \in (0, 1]$. The mechanism M satisfies only a subset of incentive constraints: for every $t \in I$ and for every $s \in I$ such that $|s - t| \leq \epsilon$,

   $$tf(t) - p(t) \geq tf(s) - p(s).$$

   Show that M is dominant strategy incentive compatible.

2. Consider the usual combinatorial auction problem, but with a simpler valuation function called the "single-minded valuation". The set of objects is $M = \{1, \ldots, m\}$. Every agent i **desires** a bundle of objects $S_i \subseteq M$. The private type of agent i is a single number θ_i. An alternative in this model can be represented by the binary variables $x_i(S) \in \{0, 1\}$ satisfying some feasibility constraints, where $x_i(S) = 1$ means bundle S goes to agent i and $x_i(S) = 0$ means bundle S does not go to agent i. Given an alternative x, denote by $\mu_i(x)$ the indicator function whether agent i gets his desire in x or not, i.e., $\mu_i(x) = 1$ if $x_i(S) = 1$ and $S_i \subseteq S$ and $\mu_i(x) = 0$ otherwise. The value function of agent i is given by $\theta_i \mu_i(x)$. Essentially, agent i realizes his value θ_i if he gets his desired set of objects.

   (a) Suppose there are four agents $\{1, 2, 3, 4\}$ and three objects $\{a, b, c\}$. The desires of agents are: $S_1 = \{a\}$, $S_2 = \{a, b\}$, $S_3 = \{b, c\}$, and $S_4 = \{a, c\}$. Suppose $\theta_1 = 7, \theta_2 = 8, \theta_3 = 2, \theta_4 = 10$.

      i. Find the efficient allocation.

      ii. Find the payment in the VCG mechanism.

3. Consider a TV channel which is selling advertisement time of 20 minutes. There are four advertisers $\{1, 2, 3, 4\}$. The length of the advertisement of advertiser i is denoted as L_i and is given by $L_1 = 12, L_2 = 7, L_3 = 7, L_4 = 10$. The advertisement lengths are publicly known. If an advertisement is displayed, then it has to be displayed entirely and the total length of all the advertisements chosen to be displayed must be less than or equal to 20 minutes.

   Advertiser i gets a value $v_i \in \mathbb{R}_+$ if its advertisement is displayed, which is his private information. The values are given as follows: $v_1 = 6, v_2 = 12, v_3 = 7, v_4 = 8$.

(a) What are the allocations and payments in the pivotal (VCG) mechanism at this profile?

(b) The TV channel is considering to use the following allocation rule. For every advertise i, it computes a real number $\kappa_i := \frac{\bar{v}_i}{L_i}$, where $\bar{v}_i$ is the reported value of agent i. The TV channel then orders the advertisers in decreasing values of κ_i. Starting from the advertiser with the highest κ_i value, the TV channel chooses advertisers with top k values of κ_i whose total length of advertisements is less than or equal to 20 and adding the $(k+1)$-st advertiser requires more than 20 minutes of length.

Use a dominant strategy incentive compatible mechanism that uses this allocation rule to compute the allocation and payments when $v_1 = 6, v_2 = 12, v_3 = 7, v_4 = 8$ and $L_1 = 12, L_2 = 7, L_3 = 7, L_4 = 10$.

4. There are four agents $N = \{1, 2, 3, 4\}$. There is a single indivisible object for sale. Each agent $i \in N$ gets a value $v_i \in \mathbb{R}_+$ if he is allocated the object or agent $(i+1)$ is allocated the object, where we maintain the convention that if $i = 4$, then $(i+1) \equiv 1$. Agent i gets zero value if any agent $j \notin \{i, i+1\}$ gets the object.

   - Suppose the values of the agents are $v_1 = 10, v_2 = 4, v_3 = 7, v_4 = 5$. Who should get the object according to the efficient allocation rule and what should be the payment according to the VCG (pivotal) mechanism?
   - Suppose we use the affine maximizer rule where we use a weight of $\lambda_i = 1$ for $i \in \{1, 2\}$ and $\lambda_i = 0.5$ for $i \in \{3, 4\}$. Assume $\kappa(a) = 0$ for all alternatives a. Who should get the object according to this allocation rule? Describe a payment consistent with a generalized Groves mechanism for this allocation rule.

5. Show that the Pivotal mechanism is the only Groves mechanism in the combinatorial auction setting which implements the efficient allocation rule and where an agent pays zero if his values for all bundles are zero.

   Further, show that the Pivotal mechanism is the only Groves mechanism in the combinatorial auction setting which implements the efficient allocation rule, which is individually rational, and where no agent is paid (i.e., payments are non-negative).