Homework 7 (48 Points)

Suggested Solutions

Part I

Multiple Choices (2 Points Each)

1. The tragedy of the commons is

   (a) a problem due to common resources being over-consumed

   (b) a problem due to negative externality

   (c) none of the above

   (d) **both a and b**

2. Which of the following is not an example of externality?

   (a) Lung cancer caused by second-hand exposure to cigarette smoke

   (b) Pollution from a factory on the health of people in the vicinity of the factory.

   (c) **Increase in health care costs on the health of individuals in society.**

   (d) Traffic accidents caused by alcohol consumption

3. Two firms, A and B, each currently dump 20 tons of chemicals into the local river. The government has decided to reduce the pollution and from now on will require a pollution permit for each ton of pollution dumped into the river. The government gives each firm 10 pollution permits, which it can either use or sell to the other firm. It costs Firm A $100 for each ton of pollution that it eliminates before it reaches the river, and it costs Firm B $50 for each ton of pollution that it eliminates before it reaches the river. After the two firms buy or sell pollution permits from each other, we would expect that

   (a) Firm A will no longer pollute, and Firm B will not reduce its pollution at all.

   (b) **Firm B will no longer pollute, and Firm A will not reduce its pollution at all.**

   (c) Firm A will dump 10 tons of pollution into the river, and Firm B will dump 10 tons of pollution into the river.

   (d) Firm A will increase its pollution and Firm B will reduce its pollution.

4. Information tend to be non-excludable because it can be spread easily, and non-rival in consumption because one person's "consumption" of information does not directly diminish another person's "consumption" of information. Hence, information tend to be a

   (a) Private good

   (b) **Public good**

   (c) Club good

   (d) Common resource

5. Suppose that Company A's railroad cars pass through Farmer B's corn fields. The railroad causes an externality to the farmer because the railroad cars emit sparks that cause $1,500 in damage to the farmer's crops. There is a special soy-based grease that the railroad could purchase that would eliminate the damaging sparks. The grease costs $1,200. Suppose that the railroad is not liable for any damage caused to the crops. Assume that there are no transaction costs. Which of the following characterizes the efficient outcome?

   (a) The railroad will continue to operate but will pay the farmer $1,500 in damages.

   (b) The railroad will purchase the grease for $1,200 and pay the farmer nothing because no crop damage will occur.

   (c) The farmer will incur $1,500 in damages to his crops.

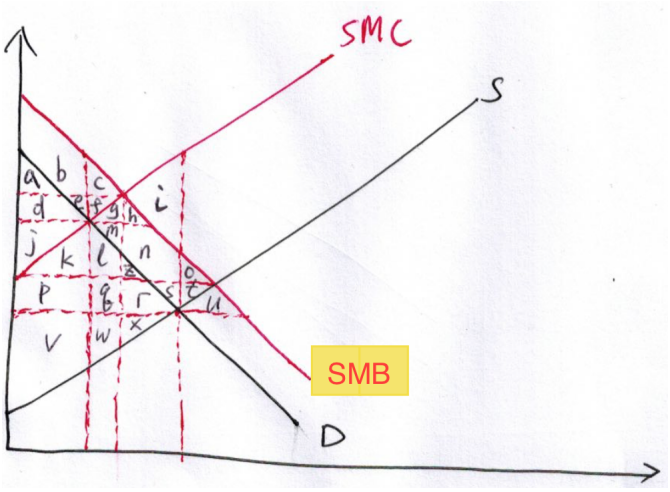
   (d) **The farmer will pay the railroad $1,200 to purchase the grease so that no crop damage will occur.**

Part II

Problems

Problem 1 (4 Points)

The following graph illustrates the market for a good that generates both positive and negative externalities[1]. Note: the government has not imposed any tax or subsidy on the market. Hence the market is at its free-market equilibrium.



SMB: social marginal benefit; SMC: social marginal cost

Find out the following:

1. Consumer surplus + Producer surplus
   `a+d+j+k+l+p+q+r+v+w+x+z`

2. External benefit
   `b+c+e+f+g+h+m+n+s`

3. External cost
   `g+h+i+k+l+m+n+p+q+r+s+v+w+x+z`

4. Deadweight loss
   `i`

[1]For example, self-driving cars can both reduce road accidents and generate pollution and congestion.

Problem 2 (8 Points)

In a village, each person has the following willingness to pay for beer:

1^{st} bottle	\$5
2^{nd}	4
3^{rd}	3
4^{th}	2
5^{th}	1
Further bottles	0

1. The cost of producing beer is \$1.50, and the competitive suppliers sell it at this price. (The supply curve is horizontal.) How many bottles will each villager consume? What is each person's consumer surplus? (2 Points)

   At a price of \$1.50, each person will consume 4 bottles of beer. Each consumer's total willingness to pay is \$14 (= \$5 + \$4 + \$3 + \$2). The total spent by each person on beer is \$6 (= \$1.50 × 4). Therefore, each consumer receives \$8 in consumer surplus (=\$14 - \$6).

2. Suppose producing beer creates pollution. Each bottle has an external cost of \$1. Taking this additional cost into account, what is total surplus per person? (total surplus per person = total surplus/number of people) (2 Points)

   Each consumer receives consumer surplus = \$8 and generates \$4 in external cost. Total producer surplus = 0, since producers are selling at marginal cost and make 0 profit. Total surplus $TS = CS + PS -$ total external cost $= 8N + 0 - 4N$, where N is the number of villagers. Therefore total surplus per person = \$4.

3. The mayor of the village imposes a $1 tax on beer. What is consumption per person now? Calculate each person's consumer surplus and total surplus per person. Based on your calculations, would you support the mayor's policy? (4 Points)

   The $1 tax raises the price of a bottle of beer to $2.50. (The entire tax will be borne by consumers because supply is perfectly elastic.) Each villager will purchase only 3 bottles at the higher price and each consumer's total willingness to pay is now $12 (= $5 + $4 + $3). Each villager pays $7.50 (= $2.50 × 3) in total. Therefore, each villager receives $4.50 ($12 - $7.50) in consumer surplus and generates $3 in external cost ($1 per bottle x 3 bottles). The government collects $3 per villager in tax revenue. Total surplus per person is therefore equal to $4.50 - $3.00 + $3.00 = $4.50. Since this is higher than $4, we should recommend the mayor's policy.

Problem 3 (4 Points)

There are three industrial firms in Happy Valley.

Firm	Initial Pollution	Cost of Reducing Pollution by 1 Unit
A	70 units	\$20
B	80 units	\$25
C	50 units	\$10

The government wants to reduce pollution to 120 units, so it gives each firm 40 tradable pollution permits.

1. Who sells permits and how many do they sell? Who buys permits and how many do they buy? (2 Points)

   B buys 40 permits and C sells 40 permits.

   Reasoning: If B buys permits from C at a price $\in (\$10, \$25)$, then both B and C would benefit from the trade. If A buys permits from C at a price $\in (\$10, \$20)$, then both A and C would benefit from the trade. Who gets to buy from C? Since B is willing to pay a price $\in (\$20, \$25)$, A would not be able to compete with B, therefore, B would be able to buy all 40 permits from C. After buying 40 permits from C, B no longer needs permits and C no longer has permits to sell, therefore, A will not participate in any trade and will keep its 40 permits[2].

2. What is the total cost of pollution abatement in this situation? How much higher would the cost of pollution abatement be if the permits could not be traded? (2 Points)

   C sells all 40 of its permits and needs to reduce its pollution by 50 units at a cost of \$10 × 50 = \$500. A still has 40 permits and needs to reduce its pollution by 30 units at a cost of \$20 × 30 = \$600. After buying 40 permits, B has 80 permits and does not need to reduce pollution. Therefore, the total cost of pollution reduction is \$1,100.

[2] What if B buys 40 permits from A instead? It could also happen, but in this case, after selling 40 permits to B at a price $\in (\$20, \$25)$, A can then buy 40 permits from C at a price $\in (\$10, \$20)$. So in the end, B will get 80 permits, A will have 40, and C will have none.

If the permits could not be traded, then A would have to reduce its pollution by 30 units at a cost of \$20 × 30 = \$600, B would have to reduce its pollution by 40 units at a cost of \$25 × 40 = \$1,000, and C would have to reduce its pollution by 10 units at a cost of \$10 × 10 = \$100. The total cost of pollution reduction would be \$1,700, \$600 higher than in the case in which the permits could be traded.

Problem 4 (4 Points)

The following table shows the marginal costs for each of four firms (A, B, C, and D) to eliminate units of pollution from their production processes. For example, for Firm A to eliminate one unit of pollution, it would cost \$54, and for Firm A to eliminate a second unit of pollution it would cost an additional \$67.

Firm	A	B	C	D
1st unit	54	57	54	62
2nd unit	67	68	66	73
3rd unit	82	86	82	91
4th unit	107	108	107	111

1. If the government charges a pollution tax of \$69 per unit, how many units of pollution would the firms eliminate altogether? (2 Points)

   Firm A would eliminate 2 units. Firm B 2 units. Firm C 2 units. Firm D 1 unit. Altogether, 7 units.

2. If the government wants to reduce pollution from 16 units to 6 units, what levels of pollution tax would achieve that goal? (2 Points)

   Tax $\in (82, 86)$ (i.e., any tax that is > 82 and < 86 would accomplish this goal)

Problem 5 (8 Points)

Four roommates are planning to spend the weekend in their dorm room watching old movies, and they are debating how many to watch. If it costs \$8 to rent a movie. Here is their willingness to pay for each film:

	Judd	Joel	Gus	Tim
First film	\$7	\$5	\$3	\$2
Second film	6	4	2	1
Third film	5	3	1	0
Fourth film	4	2	0	0
Fifth film	3	1	0	0

1. What is the total surplus if they rent 1 movie? What is the total surplus if they rent 5 movies? (2 Points)

   `1 movie:` $7+5+3+2-8=9$
   `5 movie:` $7+5+3+2+6+4+2+1+5+3+1+4+2+3+1-8\times 5=9$

2. How many movies should the roommates rent to maximize total surplus? (2 Points)
   3

3. If they choose the optimal number from 2. and then split the cost of renting the movies equally, how much surplus does each person obtain from watching the movies? (2 Points)

   `Judd:` $7+6+5-2\times 3=12$
   `Joel:` $5+4+3-2\times 3=6$
   `Gus:` $3+2+1-2\times 3=0$
   `Tim:` $2+1-2\times 3=-3$

4. Is there any way to split the cost to ensure that everyone benefits? (2 Points)

   `Split according to each person's willingness to pay`[3].

[3] However, in reality, it is hard to know each person's WTP, as people may not have the incentive to reveal their true WTP.

Problem 6 (4 points)

There are three groups in a community. Their demand curves for public television in hours of programming, T, are given respectively by

$$W_1 = \$200 - T$$
$$W_2 = \$240 - T$$
$$W_3 = \$320 - 2T$$

Suppose public television is a public good that can be produced at a cost of \$200 per hour.

1. What is the efficient number of hours of public television? (2 points)

   `Total demand for public TV:`

   $$W = 760 - 4T$$

   `Social optimum:`

   $$760 - 4T = 200 \Rightarrow T^* = 140$$

2. If the government charges each group for watching public TV at a price of \$200/hour, then it becomes excludable. In such a case, how many hours of programming would the three groups consume, respectively (2 points)

   $T_1 = 0, T_2 = 40, T_3 = 60.$

Problem 7 (6 points)

The Georges Bank, a highly productive fishing area off New England, can be divided into two zones in terms of fish population. The total daily fish catch (in tons) in Zone 1 is

$$F_1 = 200X_1 - 2\left(X_1\right)^2 \tag{1}$$

, where X_1 is the number of boats fishing there. Each boat then equally share the total daily fish catch.

The daily fish catch of Zone 2 is

$$F_2 = 100X_2 - \left(X_2\right)^2 \tag{2}$$

, where X_2 is the number of boats fishing in Zone 2. Each boat then equally share the total daily fish catch.

There are 100 boats now licensed by the government to fish in these two zones. Answer the following questions about this situation:

1. Suppose the boats are allowed to fish where they want, with no government restriction. If each boat aims to maximize its daily catch, how many will fish in each zone (the number of boats need NOT be an integer)? (2 points)

   `People will fish until the catch in each zone is the same:`

   $$\frac{F_1}{X_1} = \frac{F_2}{X_2} \Rightarrow 200 - 2X_1 = 100 - X_2 \Rightarrow X_1 = \frac{200}{3}, X_2 = \frac{100}{3}$$

   `, where` $X_1 + X_2 = 100$`.`

   `Total catch:`

   $$F_1 + F_2 = 200 \times \frac{200}{3} - 2 \times \left(\frac{200}{3}\right)^2 + 100 \times \frac{100}{3} - \left(\frac{100}{3}\right)^2 = 6666$$

2. Suppose the government wants to maximize the total daily fish catch. If the government can restrict in which zone the boats are allowed to fish, how many boats should be allocated to each zone? (2 points)

The government maximizes total catch:

$$\begin{aligned} F_1 + F_2 &= 200X_1 - 2(X_1)^2 + 100X_2 - (X_2)^2 \\ &= 200X_1 - 2(X_1)^2 + 100 \times (100 - X_1) - (100 - X_1)^2 \end{aligned} \tag{3}$$

Maximizing (3) w.r.t. $X_1 \Rightarrow X_1^* = 50, X_2^* = 50$

Total catch: $F_1 + F_2 = 7500$

3. Suppose the government wants to maximize the total daily fish catch by taxing each boat fishing in Zone 1 by an amount equal to T tons of fish per day. How much should T be (T need NOT be an integer)? (2 points)

We know that if $X_1 = X_2 = 50$, then total daily fish catch would be maximized. Hence, after taxation, we should have:

$$\begin{aligned} 200 - 2X_1 - T &= 100 - X_2 \\ X_1 &= X_2 = 50 \end{aligned}$$

$\Rightarrow T = 50$.

Problem 8 (0 Points)

There are two firms in the market, company A and company B. Without taxation, both are currently emitting 100 metric tons of greenhouse gas (GHG) each year. To reduce q metric tons of emission, the marginal abatement cost for A is $mc = 5q$. The marginal abatement cost for B is $mc = 10q$.

The government is considering charging a price for emission in the form a carbon tax.

1. Derive the market demand for GHG emission as a function of emission price.

   Given an emission price p, A will reduce $q_A = \frac{p}{5}$ metric tons of GHG. B will reduce $q_B = \frac{p}{10}$ metric tons of GHG. Thus the total pollution abatement $Q^{Abatement} = \left(\frac{1}{10} + \frac{1}{5}\right) p = \frac{3}{10}p$. Since A and B together emit 200 metric tons of GHG without tax, the market demand for GHG emission is

   $$Q^D = 200 - \frac{3}{10}p$$

2. It is determined that each metric ton of GHG emission will cause \$100 equivalent of damage to the environment. What is the marginal benefit of emission reduction? What is the optimal level of tax the government should impose?

   Marginal benefit of abatement: \$100
   Optimal level of tax: \$100

3. If, instead of taxation, the government implements a cap-and-trade system, what is the level of cap the government should set?

   Cap level = emission level under optimal tax:

   $$Q = 200 - \frac{3}{10} \times 100 = 170$$