SUGGESTED SOLUTIONS FOR MIDTERM EXAM

1. Suppose that farmers in Brazil grow coffee beans with \( MPC = 10 + 3/2Q \). The coffee beans are bought by a middleman, who sells them to consumers with \( MB = 40 - Q \). Modern production of coffee involves an environmental externality (soil erosion, loss of biodiversity, and chemical run-off). This externality has a cost of \( MEC = \frac{1}{2} Q \).

**Note – this question only requires that you calculate the answers numerically. It may help to draw a graph, but this is not required. Please show all work.**

(a) (8 points) Under the middleman, what is the output level \( Q_{MM} \), the price paid to producers \( P_{PMM} \), and the price paid by consumers \( P_{CMM} \)?

The middleman will set marginal outlay (MO) equal to marginal revenue (MR) to determine the profit maximizing quantity. Total outlay is the total quantity paid by the middleman \( (P\times Q) \), while marginal outlay is the additional amount the middleman has to pay if he buys one more unit. This is greater than simply the \( MPC(Q) \), because the middleman will have to pay a higher price on EVERY unit that he buys, not just the last one.

\[
TO = Q \times MPC(Q) = 10Q + \frac{3}{2}Q^2
\]

\[
MO = \frac{\partial TO}{\partial Q} = 10 + 3Q
\]

Marginal revenue is the additional amount that the middleman will make by selling one more unit, given that selling a larger quantity will reduce the price in the market.

\[
TR = Q \times MB(Q) = 40Q - Q^2
\]

\[
MR = \frac{\partial TR}{\partial Q} = 40 - 2Q
\]

Setting \( MR = MO \) yields the following:

\[
10 + 3Q_{MM} = 40 - 2Q_{MM}
\]

\[
5Q_{MM} = 30 \Rightarrow Q_{MM} = 6
\]

The middleman will pay the producers the \( MPC(Q_{MM}) = (10 + 3/2\times6) = 19 \). So, \( P_{PMM} = 19 \). The middleman will charge the consumers the \( MB(Q_{MM}) = 40 - 6 = 34 \). So, \( P_{CMM} = 34 \). This yields the highest profit to the middleman.

(b) (8 points) Now the government of Brazil decides to intervene and establishes regulation that leads to the competitive outcome. What is the price \( P_C \) and quantity \( Q_C \)? What is the amount of consumer surplus \( (CS_C) \), producer surplus \( (PS_C) \), and the total environmental cost \( (TEC_C) \)?

If regulation leads to the competitive outcome, then the price and quantity will be given by the intersection of \( MPC \) and \( MB \). Solving this gives:

\[
40 - Q_c = 10 + \frac{3}{2}Q_c
\]

\[
30 = \frac{5}{2}Q_c \Rightarrow Q_c = 12
\]

\[
P_c = 40 - 12 = 28
\]

Consumer surplus is the area under the \( MB \) curve and above the price. Using the formula for the area of a triangle (you could also use integration), \( CS_C = \frac{1}{2} \times 12 \times 12 = 72 \). Producer surplus is the area below the price and above the \( MC \) curve, so \( PS_C = \frac{1}{2} \times 18 \times 12 = 108 \). Total externality cost is the area below the \( MEC \) curve, so \( TEC_C = \frac{1}{2} \times 12 \times 6 = 36 \). In summary:

\[
Q_c = 12
\]
\[ P_C = 28 \]
\[ C_{SC} = 72 \]
\[ P_{SC} = 108 \]
\[ TEC_C = 36 \]

(c) (8 points) Lastly, assume that concerned citizens convince the government to pass regulation to limit pollution and land degradation. What is the socially optimal level of price \((P^*)\) and quantity \((Q^*)\)? Suppose that the government uses a tax on producers to achieve the socially optimal outcome. What is the optimal per-unit tax \((t^*)\)? What is social welfare \((SW^*)\) at this output level?

At the social optimal level, the externality will get taken into account. We calculate the marginal social cost \((MSC) = MPC + MEC = 10 + 3/2Q + 1/2Q = 10 + 2Q\). Setting \(MB = MSC\) gives the following:

\[ 40 - Q^* = 10 + 2Q^* \]
\[ 30 = 3Q^* \Rightarrow Q^* = 10, P^* = 30 \]

To calculate the optimal tax \((t^*)\), we need to set \(MPC(Q^*) + t^* = MSC(Q^*)\). Subbing in \(Q^* = 10\) gives the following:

\[ 10 + \frac{3}{2}(10) + t^* = 10 + 2Q^* \]
\[ 25 + t^* = 30 \Rightarrow t^* = 5 \]

To calculate social welfare \((SW^*)\), we want to find the area between the MB curve and the MSC curve (up until \(Q^* = 10\)). This can be solved using the area of a triangle (or integration) - \(SW^* = \frac{1}{2} \times 10 \times 30 = 150\). The other method would be to calculate \(CS^*, PS^*, GR^*,\) and \(TEC^*\). If you do this, you’ll find the following:

\(CS^* = \frac{1}{2} \times 10 \times 10 = 50\)
\(PS^* = \frac{1}{2} \times 15 \times 10 = 75\)
\(GR^* = 5 \times 10 = 50\)
\(TEC^* = \frac{1}{2} \times 5 \times 10 = 25\)

\(SW^* = CS^* + PS^* + GR^* - TEC^* = 50 + 75 + 50 - 25 = 150\)

(d) (6 points) Coffee can also be grown using a more traditional method – shade-grown coffee. This option eliminates many of the environmental problems of modern production techniques. List and briefly explain (this is not an essay, just list and briefly explain!) 3 policy options that the government could use if it wants to encourage farmers to grow shade-grown coffee.

There are lots of possible answers to this question, and anything that made sense was accepted. Here is a list of some of the possible answers (by no means is this list complete!)

- One possibility is for the government to impose a tax on environmental damage. If the tax is large enough, the cost difference could convince some farmers to switch to shade-grown coffee.

- The government could also tax the fertilizer that is a necessary input into conventionally grown coffee.

- The government could also subsidize the costs associated with switching from conventional to shade-grown coffee for farmers.

- Another possibility is to educate farmers or consumers about the environmental destruction associated with conventionally grown coffee (awareness). This could create a market for shade-grown coffee where the farmers can sell their product for a higher price than conventionally grown coffee. This can be seen in the market for Fair Trade certified coffee.
2. Suppose that there are two electrical plants in our town. The total net benefits (benefits minus private costs) that the firms derive from releasing emissions are as follows:

\[ B_1 = 30x_1 - x_1^2 \]
\[ B_2 = 50x_2 - x_2^2 \]

The marginal externality cost of the emissions on health and well-being is defined by the following expression:

\[ \text{MEC} = X, \text{ where } X=x_1+x_2 \]

After spending three hours on the computer, you have made the following graph of the relevant information (the labeled points are to assist you later in the problem to identify relevant areas):

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a) (12 points) Mathematically derive the aggregate demand curve of the two firms for emissions. Please show your work - very few points (if any) will be given if you write the right answer without showing your work! (continue your answer on the next page)

First, we find the two marginal benefit curves:

\[ \text{mb}_1 = 30 - 2x_1; \quad \text{mb}_2 = 50 - 2x_2 \]

In order to add the two demand curves horizontally, we need to first take their inverses (solve each the two equations for \( x_1 \) and \( x_2 \)):

\[ x_1 = -0.5\text{mb}_1 + 15; \quad x_2 = -0.5\text{mb}_2 + 25 \]

We add the two equations to get aggregate amount of pollution demanded (\( X = x_1 + x_2 \)):

\[ X = 40 - \text{MB} \quad (\text{where } \text{MB} = \text{mb}_1 + \text{mb}_2) \]
Rearranging, and using the graph to determine the ranges for the two segments of the kinked demand curve, we get:

$$MB = 50 - 2X \text{ over range } [0,10]$$
$$MB = 40 - X \text{ over the range } [10,40]$$

For the remaining parts of question 1 (1.b.-1.d), you may use the above graph to answer the question and are **not** required to show any calculations. If you wish to denote an area on the graph, please use the minimum number of letters that outline the area’s boundary. A line segment should have two letters, a triangle should have three letters, and a rectangle (and parallelogram) should have four letters, etc. If you have any doubts or questions about this, please ask one of the GSIs. If you need to add a point to the graph, please do so and label it.

b) (6 points) Assume that there is no pollution regulation in our town and that firms do not incur any of the externality costs of emissions. Please indicate the areas on the graph that correspond to:

- Firm 1’s producer surplus: __BRS________
- Firm 2’s producer surplus: __ATR________
- Total externality cost: ___RVU___________
- Deadweight loss: ____VHU______________

c) (6 points) If the town council were to impose a tax on emissions, what would be the per unit tax ($t^*$) in dollars/unit that would reduce emission levels to the social optimum?

___$20_________

How many units of pollution would each of the two firms emit under this tax:

- Amount of emission by firm 1: ___5___________
- Amount of emission by firm 2: ___15___________

Under the optimal tax, please indicate the areas on the graph that correspond to:

- Total externality cost: RHZ
- Deadweight loss: _0__________________

d) (6 points) Consider the case where the town council decides to impose a system of pollution permits that can be traded. The total number of permits is equal to the social optimum level of emissions and each firm initially receives the same number of permits.

How many permits would each firm buy/sell (please indicate whether bought or sold):

- Amount bought/sold by firm 1: 5 sold
- Amount bought/sold by firm 2: 5 bought

How many units of pollution would each of the two firms emit after trading:

- Amount of emission by firm 1: ___5___________
- Amount of emission by firm 2: ___15___________
Short Answer Section:

Please answer both questions (3&4) below. Each one should be answered in an essay format. Points will be taken off for answers that are not written in an organized manner, or are unnecessarily wordy. It may be useful to think about your argument before beginning to write.

3. (20 points) Consider the following two scenarios:

   a) In the middle of the North Woods, a paper mill is located upstream from a brewery. The paper mill releases waste and chemicals that pollute the river, while the brewery relies on a clean water supply to brew its famous Amber Ale (for clarification, Amber Ale is a type of beer).

   b) A toxic waste dump in Alabama has seepage that leaks into the groundwater. Groundwater is used by local residents for drinking and cleaning, in addition to supplying water for irrigation of local agriculture.

Please answer the following questions in a short essay format. (Two or three well-written paragraphs should suffice):

What does the Coase Theorem say?  What assumptions are required for it to hold? Discuss how it may or may not apply in the two scenarios described.

The Coase Theorem says that if an externality exists and property rights are well defined, then there is no need for market intervention. The parties that are affected by the externality will be able to negotiate and reach a Pareto optimal solution. In addition, the Coase Theorem says that this will happen regardless of which party has the initial property rights. Therefore, according to Coase, there is little need for government intervention in the market through the use of taxes, subsidies, quotas, or permits.

However, this requires that certain assumptions hold. The first required assumption is that property rights are well defined and enforceable. This often doesn’t hold in real life – those rights could be based on a history, efficiency, or social welfare. For example, if a rancher is allowed to have his cattle graze on public lands, and has been doing so for decades, does he have a right to use the land? What if the government decides to sell the land, despite the fact that the rancher has invested a lot of years and money into his cattle operation? The issue of well-defined property rights is not always simple, and if you don’t have an institutional setting in which you can enforce them, then they are not very useful. Another required assumption is that transaction costs are zero. If hiring a lawyer, and coordinating meetings has a cost, then the cost of negotiating may exceed the potential benefits. The last required assumption is that everyone involved has perfect information. This means that the negotiating parties each know their respective MEC and MB curves. Of course, this often doesn’t hold in real life. Even the best-trained scientists don’t always know the true effects of pollution on health or the environment, so how can we expect an average Joe on the street to know all of the relevant information?

In the first scenario mentioned above, the Coase Theorem may hold. Assuming that there are not many residents of the North Woods who also care about the pollution level in the river, the brewery and the paper mill may be able to negotiate and come to an agreement. We expect that each party know something about their potential profits of production, and the benefit/cost of cleaner water in the river. Assuming that the brewery does not need perfectly clean water for it’s Amber Ale, there is a good chance the parties could negotiate an agreement where the paper mill limits the pollution into the river, in exchange for some fee from the brewery. Maybe a few cases of beer per month for each paper mill employee would suffice to convince him or her to pollute the river less.

In the second scenario mentioned above, the Coase Theorem will probably not hold. There are a few reasons for this. The first reason is that the number of people in the affected party is very large. Not only are residents of the area affected, but also people who eat the produce that has been irrigated with the polluted water. The transaction costs of coordinating all of those people would be enormous. Also, there would be a lack of full information. It is very difficult to isolate and measure the true cost of the pollution...
on health and the local environment. For these reasons, it is unlikely that a Pareto optimal solution could be reached through negotiation.

4. (20 points) This short essay deals with the heterogeneous demand for public goods and which mechanisms or management options can be used to provide public goods. In your essay, please address the following points (altogether, two to three well written paragraphs should be sufficient):
   a) Discuss and contrast the efficiency and distribution of welfare in a world with two different demand curves under different management mechanisms (government, concessionaire, and monopolist).
   b) Name and briefly describe at least two alternative or hybrid management mechanisms or options other than the three listed above.

Government provision of the public good can achieve the social optimal level of provision and can be designed so as not to exclude individuals. If price discrimination (charging of two different entrance fees) is feasible, public goods provided by a concessionaire or a monopolist can also be efficient. If price discrimination is not feasible, then both the concessionaire and the monopolist might under-provide the public good and/or exclude individuals from using it. In particular, while the government can mandate the concessionaire to provide the optimal amount of the good, the price they charge may exclude certain users. The monopolist may not find it profitable to even supply the socially optimal level of the good, and his prices are even more likely than the concessionaire to exclude “low-value” consumers. This is inefficient for society. Don't forget that it might also be important to compare the costs of provision. It is possible that the marginal provision costs are significantly less for a concessionaire or monopolist. If the cost savings were significant, it is possible for the concessionaire or monopolist to be more efficient than the government.

Under the government management option, consumers receive the most consumer surplus (and producers receive no profits). Consumers receive less surplus under the concessionaire and very little under the monopolist (0 if the monopolist can price discriminate). Meanwhile, producers receive "fair" profits under the concessionaire and considerably more under the monopoly.

Management options are not limited to the three discussed above. The government can operate the park through price discriminating entry fees (special fees for seniors, students, frequent users, etc.). Individuals with relatively higher WTP can cross-subsidize those with less WTP. A common option is to run the park through a governmental agency but to lease out the provision of various amenities to (regulated) private firms (i.e. lodges, restaurants, gift shops, adventure tours, etc.).

As discussed in class, donations are often solicited from special interest groups or wealthy individuals who might give for benevolent, financial (tax write-off) or "egotistical" reasons (if they get a park or building named after them). It is important to point out that many public goods are maintained through community norms, values, and rules (especially in small communities in rural U.S. or developing world) that prevent or limit free-riding problems. Similarly, many parks are assisted by civic-minded volunteers who donate their time and energy (i.e. boy scouts who clean up or maintain sites or senior citizens who volunteer as guides) to maintain public goods.

There are many other possible alternatives, this was simply meant to give some ideas and examples.