1. **(Public Goods)** You have just received an important assignment as a consultant to the Prime Minister of a small country called Zilbermania. The Prime Minister is seeking advice on how to best manage a long-neglected but beautiful wildlife reserve called Giannini Park. Giannini Park has a total area of 100 acres, and the annual marginal maintenance cost (MC) is: \( MC = 2A \) where \( A \) is the number of acres maintained. Using the valuation tools acquired in EEP101/ECON125, you have estimated the willingness to pay for acres of maintained park by the country's 5 citizens to be: \( m_b = 20 - .4A \) (for each citizen, where \( A \) is the number of maintained acres). Assume that \( m_b = 0 \) (i.e. citizens never dislike the park being maintained).

a) The Prime Minister would like to see a report of the following (including your calculations):

i. What is the aggregate demand for acreage in Giannini Park and the optimal amount of maintained acres? Graph the aggregate demand and marginal cost curves as well as the optimal level of acreage.

The following graph corresponds to all parts of question 1.a:
Since Giannini Park is a public good, we determine aggregate demand by vertically summing each consumer’s demand. Adding up the 5 individual mb demand curves gives us:  $MB_1 = 100 - 2A$. The socially optimal supply of Park acres is where aggregate demand (marginal benefit) is equal to marginal cost:

$$100 - 2A = 2A$$
$$100 = 4A$$
$$A^* = 25$$

**ii. How much would the annual budget expenditure be if the optimal level of acreage in Giannini Park were maintained through the use of the central government’s tax revenues? How much would each citizen pay in taxes for the park? Please label the area corresponding to budget expenditures and total consumer surplus (total consumer surplus for all citizens) on your graph.**

The total cost (TC) of supplying the optimal number of maintained acres is equal to the area under the MC curve up to $A=25$.

$$TC = \frac{1}{2}bh \text{ (area of triangle)}$$
$$TC(A^*) = \frac{1}{2}(25)(2*25)$$
$$TC(A^*) = $625$$

The governmental expenditure would be $625. Assuming each citizen pays the same amount in taxes, they would each pay:

$$\text{Per person tax} = \frac{625}{N}$$
$$\text{Tax} = \frac{625}{5} = $125$$

On the graph, budget expenditures corresponds to the triangle, FA*C. Total consumer surplus is the area ACF.

**iii. The Prime Minister is considering granting a concession to a private firm to operate the park (and the right to charge a “fair” admission fee equal to the shadow value of park acres to society). Suppose the firm were able to operate the park more efficiently than the government ($MC=$1.8A). What would be the number of maintained acres in Giannini Park, how much would the per-person entrance fee be, what is the firm’s profit and consumer surplus for society? Please label the number of maintained acres, shadow value of acres, consumer surplus, and firm profits (producer surplus) on your graph (or a new one if you wish).**

The government allows the concessionaire to charge a per-acre fee equal to the shadow value of park acres to society (value or price of an additional acre when marginal social cost equals marginal social benefit). First, set aggregate demand equal to marginal cost, to get the optimal number of acres:

$$100 - 2A = 1.8A$$
$$100 = 3.8A$$
$$A_c^* = 26.3$$

The shadow value (lambda) of an additional acre is just the value to society of one acre at $A_c^*$ or aggregate demand at $A_c^*$:

$$AD(A_c^*) = 100 - 2A^*$$
$$AD(A_c^*) = 47.4$$

The total revenue that the concessionaire will receive is just 47.4 (price per acre) times the total number of acres or: $(47.4)(26.3)= 1246.6$

The concessionaire will set the per-person entry fee equal to total revenue divided by the number of consumers: $1246.6/5 = 249.3$

Before calculating the firm’s profits, we need to calculate the total costs incurred by the concessionaire. This is the area under the concessionaire’s marginal cost curve:

$$TC = \frac{1}{2}bh \text{ (area of triangle)}$$
$$TC(A_c^*) = \frac{1}{2}(26.3)(1.8*26.3)$$
$$TC(A_c^*) = $623.3$$

Firm profits are total revenues minus total costs:

$$? = 1246.6 - 623.3 = 623.3$$
Total consumer surplus is the area below the aggregate demand curve but above the price (shadow price in this case) line:

\[ CS = \frac{1}{2}(b \times h) \text{ (area of triangle)} \]

\[ CS = \frac{1}{2}(26.3)(100 - 47.4) \]

\[ CS = 691.7 \]

On the graph, the number of maintained acres is \( Ac \) and the shadow value of acres is where point D is located. Total consumer surplus is AED and firm profits are FED.

iv. If the Prime Minister were to give the park over to his (greedy) brother to run, how much of the park would his brother decide to maintain (at \( MC = $2A \))? What would be the per-visitor entry fee, consumer surplus, and firm profits? Please label consumer and producer surplus on your graph.

Since the brother is “greedy” and there was no mention of regulation, we can assume he would operate as a monopolist and operate until his marginal revenue equals his marginal cost. Thus, \( A_M^* = A^* = 25 \) (monopolist provides same number of acres as under the social optimum).

The monopolist would extract all of the willingness to pay of the visitors. The area of this parallelogram (area under \( MB_1 \) curve up to \( A_M^* \)) is:

\[ WTP = \frac{1}{2} (h_1 + h_2)b \text{ (area of parallelogram)} \]

\[ WTP = \frac{1}{2}(100 + 50)(25) \]

\[ WTP = 1875 \]

Total revenue received by the monopolist is thus 1875. The per-visitor entry fee is simply:

\[ \text{Entry Fee} = 1875/5 = 375 \]

Consumer surplus is equal to 0 (all willingness to pay is extracted by monopolist).

Producer surplus is equal to total revenue minus total costs:

\[ ? = 1875 - 625 = 1250 \]

On the graph, producer surplus is the area ADA*F, and there is no consumer surplus.

b) You have just met with the Minister of Tourism and he says that you can expect 5 foreign tourists to visit Zilbermania each year. The willingness to pay (by each foreign tourist) for visiting Giannini Park is estimated at: \( mb_2 = 40 - .5A \). Assume that \( mb_2 = 0 \) (i.e. foreign tourists never dislike additional park acres being maintained). Please show your calculations (the Prime Minister wants to be able to easily double-check your work) for the following questions:

i. What is the new aggregate demand for acreage in Giannini Park, the optimal amount of maintained acres, and the new levels of government expenditures required to maintain the park? Graph the aggregate demand and marginal cost curves, government expenditures, and optimal level of acreage.
Our aggregate demand curve is the vertical summation of all individual demand curves. The aggregate demand curve will be kinked: one segment (0-50) will include all locals and foreigners while the other segment will be relatively flatter, reflecting only the demand of the 5 foreigners (from A between 50 and 80). Actually, there is one more segment: for A greater than 80, MB\(_{1,2}\) = 0.

\[ MB_1 = 100 - 2A \text{ (sum of five locals)} \]
\[ MB_2 = 200 - 2.5A \text{ (sum of five foreigners)} \]
(segment 1) \[ MB_{1,2} = 300 - 4.5A \text{ for } 0 = A = 50 \]
(segment 2) \[ MB_{1,2} = 200 - 2.5A \text{ for } 50 = A = 80 \]
(segment 3) \[ MB_{1,2} = 0 \text{ for } 0 = A \]

To find A*, we can set MB\(_{1,2}\) = MC. By looking at the graph we can tell that MC will intersect MB\(_{1,2}\) on the first (steeper) segment. Thus, A* is:

\[
MB_{1,2} = MC \\
300 - 4.5A = 2A \\
300 = 6.5A \\
A^* = 46.15
\]

*Note: if we had set the second segment of MB\(_{1,2}\) equal to MC (i.e. not looked at our graph), we would have calculated:

\[
MB_{1,2} = MC \\
200 - 2.5A = 2A \\
200 = 4.5A \\
A^* = 44.44
\]

Since this is not in the interval (50,80), this answer is inconsistent and we must discard it.

As before, government expenditures is simply the area under the marginal cost curve up to A*.

\[
TC = \frac{1}{2}(b*h) \text{ (area of triangle)} \\
TC(A^*) = .5(46.15)(2*46.15)
\]
TC(A*) = 2129.82
The governmental expenditure would be $2,129.82. On the graph, this is the area of the triangle FA*C.

ii. Suppose that the government decided to fund the park at the social optimum entirely through a tax on foreigners (i.e. extra airport tax or visa fee- assume that it will not affect the number of visitors coming to Zilbermania). Calculate and compare the total consumer surplus of citizens and of foreign tourists. Label these areas on the graph.

The total benefits or total willingness to pay derived by local citizens (WTP$_L$) and foreign visitors (WTP$_F$) are simply equal to the area under their respective aggregate demand curves up to A=46.15. Note that I am treating all local citizens as one group and all foreign visitors as one group- it is also possible to derive these calculations for each foreign individual and local individual.

\[
WTP = \frac{1}{2} (h_1 + h_2)b \quad \text{(area of parallelogram)}
\]

\[
WTP_L = .5(100 - 7.7)(46.15) = 2485
\]

\[
WTP_F = .5(200 + 84.6)(46.15) = 6567.14
\]

The total consumer surplus of local citizens is just their total willingness to pay since they are not paying any taxes or entrance fees. The total consumer surplus of foreign visitors is their WTP minus the total tax they are required to pay.

\[
CS(\text{local}) = 2485
\]

\[
CS(\text{foreign}) = 6567.14 - 2129.82 = 4437.32
\]

Total CS(local) is the area BDA*F on the graph, while CS(foreign) is the area ACF.

iii. If the (greedy) brother were operating the park and he could not distinguish between foreign and local tourists, what level of acreage and entry fee per person would he charge?

Since the monopolist (the brother) can not distinguish between foreign and local visitors, he must set one single fee. If he could distinguish, he would simply charge each type of visitor their maximum willingness to pay (2 different entry fees). The monopolist has two options: 1) set the entrance fee high and only serve foreign visitors, or 2) set the entrance fee low and serve both foreign and domestic visitors. The way to solve this problem is to calculate the total profits under option 1 and option 2, then determine which yields more profits.

Option 1) High fee. The monopolist realizes that he is only serving the foreign tourists, so he produces until MB$_2$=MC:

\[
200 - 2.5A = 2A
\]

\[
200 = 4.5A
\]

\[
A_{M1} = 44.44
\]

The total benefit of the foreign visitors is calculated in the same manner as before:

\[
WTP_F = .5(200 + 88.88)(44.44) = 6,418.9
\]

The monopolist would extract the entire WTP$_F$, so the per person entry fee is: \((6418.9)/5 = 1283.8\). The monopolist's profits would be his total revenue minus his total costs. First we need to calculate total costs:

\[
TC = \frac{1}{2} (b*h) \quad \text{(area of triangle)}
\]

\[
TC(A_{M1}) = .5(44.44)(2*44.44) = 1974.9
\]

Profits are then:

\[
? = 6,418.9 - 1974.9 = 4444.0
\]

Option 2) Low fee. The monopolist will set the lower fee such that he extracts the maximum WTP of local visitors. The foreigners would pay the same price as the locals. Thus, the monopolist would treat all individuals (both rich and poor) as if they were all poor. The aggregate demand curve is the same as if there were 10 local visitors, or 10 times the demand curve of a local individual (mb1). Let's call this aggregate demand curve MB2 (total MB under option 2):

\[
MB2 = 10^* (20 - .4A)
\]

\[
MB2 = 200 - 4A
\]
To find how many acres the monopolist would supply under option 2, we set MB2 equal to his marginal cost:

\[ MB2 = MC \]
\[ 200 - 4A = 2A \]
\[ 200 = 6A \]
\[ A_M2 = 33.33 \]

The total benefit of the 10 visitors is calculated in the same manner as before:

\[ WTP_2 = .5(200 + 66.66)(33.33) = 4443.9 \]

Again, the monopolist's profits are his total revenue minus his total costs. First we need to calculate total costs:

\[ TC = \frac{1}{2}(b*h) \text{ (area of triangle)} \]
\[ TC(A_{M2}) = .5(33.33)(2*33.33) \]
\[ TC(A_{M2}) = 1110.9 \]

Profits are then:

\[ ? = 4443.9 - 1110.9 = 3333 \]

We see that profits are greater under the first option \((4442.9 > 3333)\), so the monopolist would set the entrance fee to admit only the foreign visitors.

c) An NGO has offered to donate $2,000 per year to assist in the operational expenses of the park as long as the government of Zilbermania meets the following three conditions: a) the park must be managed by the government, b) no entrance fee is to be charged for local tourists (foreign tourists may be charged an entrance fee; assume park officials can determine who is a local and a foreigner), and c) the entire 100 acres of the park must be maintained.

Calculate how much the government should charge each of the foreign tourists and how much additional money (if any) they will need from their central budget if they were to accept the offer and meet the conditions.

The total cost of maintaining the 100 acres is calculated in the same manner as before:

\[ TC = \frac{1}{2}(b*h) \text{ (area of triangle)} \]
\[ TC(A_{NGO}) = .5(100)(200) = 10,000 \]

Since the NGO is donating 2,000, we need to receive 8,000 from foreign tourists if we want to cover the costs without spending additional money from the central budget. First, we calculate the total WTP of foreign visitors, the area under their aggregate MB curve:

\[ WTP = \frac{1}{2} (b*h) \text{ (area of triangle)} \]
\[ WTP = .5(80)(200) = 8,000 \]

We see that we can set a high enough fee on foreigners to cover the entire cost of maintaining the park without spending additional money from the central budget. Each foreigner would pay a per person entrance fee of:

\[ 8,000/5 = 1600. \]

2. **(Technology Adoption)** The Prime Minister has just read the following press release from the University of California, Berkeley:

> Worldwide, almost two billion people rely on wood, charcoal, dung, and crop residues as their primary cooking fuels. Respiratory infections, causally linked to exposure to particulate matter and other pollutants in smoke from cooking fires, are the leading cause of illness in many developing nations. This environmental pollution accounts for approximately 4% of the total global burden of disease.1

The Prime Minister is aware of the fact that all five of his citizens use wood to cook their food. He worries about the high levels of pollution and the effects on health. He is happy with your work so far and has requested you to remain for another couple of weeks to help him formulate a policy that would help reduce this pollution problem (if you finish early, you can spend a week at the beach).

---

Your field research team has found the following information:

1.  \( Y = \sqrt{e} \)
   where \( Y \) = output (total amount of heat generated), \( e \) = amount of effective inputs

2.  \( e = h(a) \)
   where \( h(a) \) is the percentage of input used in production, \( a \) is the amount of fuel input used in one year

3.  \( Z = (1-h(a))aTF \)
   where \( Z \) = annual pollution emission units, \( T \) = total cooking time in hours over one year, \( F \) = parameter representing fuel-specific pollution characteristics

<table>
<thead>
<tr>
<th>Wood fires</th>
<th>Gas stoves</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h(a) )</td>
<td>.25</td>
</tr>
<tr>
<td>( a_i )</td>
<td>16</td>
</tr>
<tr>
<td>Price per unit of fuel input</td>
<td>5</td>
</tr>
<tr>
<td>( T )</td>
<td>400</td>
</tr>
<tr>
<td>Average hourly wage</td>
<td>$ .50 per hour</td>
</tr>
<tr>
<td>( F )</td>
<td>.8</td>
</tr>
<tr>
<td>Cost of purchasing technology (i.e. stove)</td>
<td>0</td>
</tr>
</tbody>
</table>

Let us assume that there are no credit constraints, that all citizens are identical and that they are all rational. Let us assume that if the net gains from switching to gas stoves are positive over the first year, then all citizens will switch. Remember to consider the input costs for fuel (valued at the unit price for fuel) as well as for time (valued at the hourly wage). Show your calculations for each of the following questions. Note these questions are not cumulative (i.e. in question iii, we are no longer assuming the government is giving away stoves as was stated in question ii, etc.).

1. Calculate the net gains from switching from wood cooking fires to gas stoves for the first year of adoption (note \( T \) and \( a \) are already expressed in annual units). Assume the citizens attach no value to pollution (and there is no pollution tax).

Since we are already told the amount of inputs used under each technology, we do not need to do the first step of determining the profit maximizing level of inputs. We can use the standard equation for determining the net gains to adoption (as presented in lecture):

\[ NG = pP - W1F - A1F - W0F - AT \]

Let, us try to plug in numbers into this general formula. Since we are told that the citizens attach no value to pollution, \( V = 0 \). Also, we are reminded that there are two separate inputs with their corresponding prices: fuel and time. Therefore, our net gains equation will be:

\[ NG = P(Y1 - Y0) - (W1F - A1F) - W0F - AT \]

Where:

- \( Y1 \) is the output under new technology (gas stoves), \( Y0 \) is the output under the old technology (cooking fires),
- \( W1F \) is the price of fuel for the new technology, \( A1F \) is the amount of fuel used for the new technology, \( W0F \) is the price of fuel for the old technology, \( A0F \) is the amount of fuel used for the old technology, \( W_T \) is the "price" or opportunity cost for time, \( T_1 \) is the amount of time used under the new technology, \( T_0 \) is the amount of time used under the new technology, \( k_i \) is the cost of adopting the new technology, \( k_0 \) is the cost of adoption the old technology.

We have numbers to plug in or means to calculate each of these parameters except for \( P \), the price of output. We will soon see that we do not need \( P \), since \( ?Y \) equals 0. In other words, the output has been normalized to be the same under both technologies; we are only worried about minimizing total costs.
To calculate \( Y_1 \) and \( Y_0 \), we first calculate \( e_1 \) and \( e_0 \):

\[
e_0 = h_0(a) a_0
\]

\[
e_1 = (.25)*(16) = 4
\]

\[
e_1 = h_1(a) a_1
\]

\[
e_1 = (.5)*(8) = 4
\]

Solving for \( Y_1 \) and \( Y_0 \),

\[
Y = e_1^{1/2}, \quad Y_0 = 2, \quad Y_1 = 2
\]

Our net gains equation is now (after eliminating \( P ? Y \)):

\[
NG = - (W_1 A_1 F - W_0 A_0 F) - W_T (T_1 - T_0) - (k_1 - k_0)
\]

Plugging in the corresponding values, we have:

\[
NG = - [(25*8) - (5*16)] - (.5)*(200 - 400) - (30 - 0)
\]

\[
NG = -(200 - 80) - .5(-200) - 30
\]

\[
NG = -120 + 100 - 30
\]

\[
NG = -50
\]

The net gains (using one year as the timeframe) from adopting the gas stoves is negative 50 dollars. No one would adopt.

\[\text{ii. If the government decided to give stoves away to all citizens, would they use them? Explain why or why not.}\]

If the government gave away gas stoves, the citizens would still choose not to use them because the input costs under the gas stoves are still higher than that of cooking fires. The net gains would improve from -$50 to -$20, but this is still negative, so no one would adopt.

\[\text{iii. Advise the Prime Minister on what would be the minimum per unit subsidy on gas in order to encourage everyone to switch to using gas stoves.}\]

We can use algebra to solve this problem. We use the same net gains equation as before, but now we solve for the price of gas (\( X \) in the formula below) that will just make citizens indifferent to adopting gas stoves. We are looking for the value of \( X \) that will make \( NG = 0 \).

\[
NG = - (X*8) - (5*16)) + 100 - 30 = 0
\]

\[
-8X + 150 = 0
\]

\[
X = 150/8 = 18.75
\]

Therefore, in order for citizens to adopt, they would need the price of gas to be 18.75 per unit. The current price is 25 per unit. The government would need to provide a subsidy of $6.25 per unit (25-18.75).

\[\text{iv. Although taxing pollution would not be feasible, you decide that one alternative would be to launch an education/awareness campaign that would make citizens aware of the negative effects of smoke on their health. What would be the minimum value for (each unit of) pollution that such an education campaign would need to “generate” in order for the citizens to adopt gas stoves? (hint: mathematically, this is the same as a per unit pollution tax)}\]

We can use the same algebraic technique to solve for the value \( V \) (value attached to pollution) that solves the equation when net gains equals 0. Let's first solve for \( Z_1 \) and \( Z_0 \), the level of pollution under each technology:

\[
Z_1 = (1 - h(a)) a_T F
\]

\[
Z_1 = (.5)*8*200*.4
\]

\[
Z_1 = 320
\]

\[
Z_0 = (.75)*16*400*.8
\]

\[
Z_0 = 3840
\]

After plugging this into the net gains formula, we set \( NG = 0 \) and solve for \( V \):

\[
NG = - (W_1 A_1 F - W_0 A_0 F) - W_T (T_1 - T_0) - V(Z_1 - Z_0) - (k_1 - k_0) = 0
\]

\[
-(200 - 80) - .5(-200) - V(-3520) - 30 = 0
\]

\[
-120 + 100 + 3520V - 30 = 0
\]

\[
3520V = 50
\]

\[
V = .014
\]
Currently, citizens place no value on pollution. The education campaign would attempt to make citizens aware of and internalize the health (and/or environmental) costs of smoke from cooking fires. The value that citizens would need to attach to each unit of pollution in order for them to choose to adopt gas stoves would be $.014.

3. **(Short Essay)** Your short but exciting career as an international management consultant has left you exhausted and unsatisfied. You have decided to take a position as a university lecturer. You decide to use your experiences in Zilbermania for one of your seminars on optimal management of public goods (refer to question 1). Address the following issues in less than 1 page handwritten (or less than ½ page typed, single space). Note this is somewhat shorter than in previous problem sets.
   
i) Why the wildlife reserve might or might not be considered a pure public good.
   
ii) Which management policy you decided to recommend to the Prime Minister and why? Make sure to include a brief analysis of efficiency, distribution of welfare, and feasibility.

In this seminar, I will briefly discuss my experiences in analyzing management options for public goods while serving as a consultant for the Prime Minister of Zilbermania. First of all, let me explain a little about what I mean by “public good,” and why the wildlife reserve might or might not be considered a “pure public good.” A public good is a good that is both completely non-rival and non-excludable. The wildlife reserve definitely has elements of a pure public good. More than one person can use the wildlife reserve, even at a given time without preventing others from benefiting from the reserve. Also, if the wildlife reserve were large or if it were impossible to build fences because of conservation concerns, the reserve could be considered non-excludable (without a fence, people might be able to enter without paying entry fee).

Despite these elements of a public good, the wildlife reserve might be considered neither completely non-rival nor completely non-excludable. In order for it to be non-rival, it must be the case that consumption of the same good by another will not diminish the benefits of others. As discussed in class (and is clearly evident at parks such as Yosemite on a nice summer day), too many people (congestion) can decrease everyone's marginal benefits of a public good. In terms of excludability, we have considered the case where we can build a fence (or otherwise control access) and exclude people from using a public good unless they pay an entrance fee. In the case of a wildlife reserve, one could argue that it is indeed excludable (especially if it is only 100 acres).

Therefore, I would classify the wildlife reserve as a public good, but not a pure public good.

In considering an optimal management mechanism for the wildlife reserve, one needs to consider issues of efficiency, distribution of welfare, and both technical and political feasibility. The three most common management mechanisms include: government operation of the park (through revenues from entry fee or taxes), permitting a private firm to operate the park and earn regulated profits (concessionaire), and permitting a single firm to operate the park and earn unregulated profits. I will share with you some of my research findings for the case where there is heterogeneous demand for the reserve: there are 5 local citizens and 5 foreign visitors with different demand curves for the reserve.

Once the NGO made its offer (see question 1.c), I immediately urged the Prime Minister to accept it. Under the NGO plan: consumers received the maximum consumer surplus possible, the government did not have to make any additional expenditures out of its general budget, and the park was maintained at its full size (if there are any positive externalities associated with existence). It is true that this was a socially inefficient solution and that foreigners paid the burden of extra costs. However, the Prime Minister was more concerned with the distribution of welfare and in particular more interested in the well-being of his citizens than that of foreign visitors (especially since I was told that even with the higher fees, the foreigners would still come to Zilbermania). In terms of political feasibility, there is a tremendous advantage to the NGO plan over any other option. In terms of technical feasibility, there is perhaps a slight advantage to government management of the reserve as long as corruption is not a problem. Governments might have less conflict of interest in maintaining the park than a concessionaire or a monopolist (which is probably why the NGO made it a condition that the government manage the reserve).

Other answers are equally (or more) correct- this is just an example of the type of short essay we might expect.