True/False/Uncertain

For each question, state clearly whether you find the statement to be true, false, or uncertain. Then provide a clear explanation. Answers without explanation will be given zero points.

1) Hockey is a public good.
Uncertain. It’s not a pure public good. If we’re talking about attendance of a hockey game, then the good is clearly excludable (you need a ticket to get in) and it’s rival to the extent that once the seats are full, one person’s presence excludes another from viewing.

Hockey on television is less excludable and is entirely non-rival. So arguably it’s more of a public good. Excludability is the issue here. If it’s shown on free TV (as opposed to cable), then anyone can watch it. But can people watch it without paying? Depends how you view advertising. In order to watch a hockey game on TV, you’re basically forced to watch advertising (you have to engage in costly activities to avoid the ads). This can be viewed as a form of admission fee, which implies excludability. So it’s certainly not a pure public good, but it’s also not a pure private good. Hence it’s likely to be underprovided (as some are now sorely aware). This could be used as justification for government intervention in the current labour dispute.

2) The free-rider problem tends to get worse as the number of beneficiaries from a public good rises.

True. The free-rider problem arises when you believe someone else will provide the good for you. The more people there are to provide the good for you, the more you can rely on those other sources of provision. Also, the more people there are, the more the gap is between one person’s personal valuation of an extra unit of the good, and societies marginal valuation of the good. Free-riding on things like doing the dishes is much less likely to be a problem when you have one roommate, than when you have ten.
3) Because drivers of cars have their own life on the line, they will exert the efficient level of care when driving.

*False.* *We can think of driver carefulness as a good with an associated positive externality.* My being careful benefits me primarily, but also has spillover benefits for others on the road. I’ll be careful up to the point where the marginal benefit to me equals the marginal cost to me. But others are benefiting as well from my care, implying that the MSB curve lies above my private MB curve. Thus, I will be providing too little care, from a social welfare (efficiency) perspective.

*Just because my life is on the line doesn’t mean I take sufficient care to account for the external benefits.*

4) Assuming you and I benefit from a public good, your marginal benefit for the last unit consumed must equal my marginal benefit from the last unit consumed, for efficiency to hold.

*False.* For private goods where everyone consumes at least some of the good, MB for person A must equal MB for person B in order for efficiency to hold. Otherwise we could take some of the good away from the person with lower marginal benefit and give it to the person with higher marginal benefit, while compensating the person with the lower marginal benefit. This would increase overall social welfare. Hence with private goods, MB must be equal across all consumers for each good consumed.

For public goods, this is not the case. All consumers consume the same amount of the good. For some, the last unit of the good may give very little benefit. For others, it may give pretty significant benefit. Suppose I get MB=1 out of the last unit consumed and you get MB=4. If the two of us make up society as a whole, then we know that as long as Q is such that MC=5, the good is being efficiently provided. We don’t need our individual MBs to be equal.

5) In equilibrium, without government intervention, a public good will be provided to a level such that MC=MB.

*False.* *Under certain strong assumptions, it can happen, but in general it won’t.* Because of free-riding (due to the non-rival, non-excludable nature of public goods), the good will tend to be underprovided. Hence, in equilibrium we will expect MSB>MSC (or MB>MC if you prefer).

6) In general, social welfare will be maximized by entirely eliminating pollution. *False.*
We can see this in the case of a single good with an associated pollution externality. Consider production of paper.

The maximum social welfare that can be achieved is denoted by the triangle between the Demand curve and MSC up to the efficient quantity. Note that if production of paper were reduced to zero, social welfare would go to zero. Naturally, we’d prefer positive social welfare to zero social welfare.

Now there may be some specific cases where the marginal external cost of an activity is so high that it warrants none of the activity taking place. In other words, where the optimal level of pollution is zero. Suppose some billionaire pyromaniac decided to buy up a chunk of land in Alberta on which to hold fireworks shows that involved detonating small nuclear weapons. Clearly he and some of his friends might greatly enjoy this activity. But it could be that the social costs associated with this would exceed the private benefits of the people in his audience. In that case, the socially optimal level of the polluting activity would be zero. In general, however, it is not socially optimal to completely eliminate pollution.

7) The Coase Theorem could be used to solve the problem of global warming.

False. The Coase Theorem is only applicable when bargaining is costless and there is perfect observability of the activity with the associated externality. Millions of firms would have to negotiate with billions of consumers to settle on agreements to reduce carbon emissions. And it would be difficult to cheaply monitor each firm to make sure it was conforming to whatever contract it signed with consumers to reduce its emissions.

8) For a per-unit tax to correct a negative production externality, it must shift the MPC so it perfectly overlays the MSC curve.

False. For a per-unit tax to correct a negative production externality it must shift the MPC so that it passes through the point where MSC=MSB. It would also work if it were shifted so it perfectly overlays the MSC curve. But it’s sufficient for it to just pass...
through the point where MSC=MSB. See example of a tax correcting a negative externality on Page 24 of the updated externalities notes.

9) A per unit tax imposed on a market with no externality and perfect information can increase social welfare.

False. In a perfectly functioning market, social welfare will be maximized at the equilibrium. The first fundamental theorem of welfare economics tells us this. So a per unit tax in that ideal situation can only make things worse.

Short Answers

A partial tour of equilibrium, market success, and market failure

1) Consider the market for slices of pizza. Suppose that the market is perfectly competitive. There are 4 consumers and 2 producers (but each acts as price taker). Consumers are identical and producers are identical. Assume that partial slices of pizza may be produced and consumed.

individual demand curve: \( q=6-P \)
individual supply curve: \( q=P \)

a) Write an equation for the market demand curve. Why does the demand curve slope down?

Pizza is a private good. Therefore to obtain market demand, we horizontally aggregate the individual demands. Thus \( Q=24-4P \). To convince yourself, draw the four individual demand curves so they are lined up horizontally. Then draw a fifth set of axes. How much is the sum of individual demands at \( P=8 \)? (plot the point) at \( P=6 \)? (plot the point); at \( P=4 \)? (plot the point); etc. down to \( P=0 \).

The demand curve slopes down because as consumers eat more pizza, their desire for more (on the margin) declines. Therefore their willingness to pay declines as they consume more. If you’ve been stranded in a blizzard for 3 days without food, your marginal WTP for the first slice will be huge. Once you’ve eaten 20 slices, your marginal WTP will probably be quite small, or even negative.

b) Write an equation for the market supply curve. Why does the supply curve slope up?

Again, we horizontally aggregate the individual supply curves. This gives market supply of \( Q=2P \). Complete the same exercise as in (a) if you’re not entirely convinced.

The supply curve slopes up (in the short run) due to some input into production being fixed (typically we assume this is capital). As more labour is combined with the fixed amount of capital, labour productivity (marginal product of labour) falls. This causes
the cost of an extra unit to rise, as more stuff is produced (and more labour is used). Hence MC is thought to slope up. MC above average variable cost is an individual firm’s supply curve.

c) Find equilibrium price and quantity in the market for pizza slices. How many slices does each person consume? How many does each producer make?

\[ D: Q=24-4P \]
\[ S: Q=2P \]

Set this equal to find equilibrium \( P \).
\[ 24-4P=2P \]
\[ 6P=24 \]
\[ P=4 \] (plug this into either \( D \) or \( S \) to get equilibrium \( Q \))
\[ Q=8 \]

Each consumer faces \( P=4 \); plugging this into individual demand, \( q=6-P \), yields \( q=2 \), so each consumer buys 2 slices.

Each producer faces \( P=4 \); plugging this into individual supply, \( q=P \), yields \( q=4 \), so each producer supplies 4 slices.

d) Calculate the total benefit derived from the equilibrium consumption of pizza. Draw a picture and shade in the area representing total benefit.

\( TB \) is given by area under demand curve up to \( Q=8 \). This is $40. \( TB= \)

e) Calculate the total variable cost of the equilibrium quantity of slices produced. Draw a picture and shade in the area representing total variable cost.

\( TVC \) is given by area under supply curve up to \( Q=8 \). This is $16. \( TVC= \)

f) Calculate consumer surplus. Draw a picture and shade in the area representing CS.

\( CS \) is \( TB \)-expenditure, where expenditure is \( P \times Q \). In this case \( CS=40-32=8 \).

\( CS= \)

g) Calculate producer surplus. Draw a picture and shade in the area representing PS.

\( PS \) is Total Revenue-\( TVC \). In this case, \( PS=32-16=16 \). \( PS= \)
h) Is the equilibrium quantity efficient? Why?

In the absence of any externality, \( S = MSC \) and \( D = MSB \). Therefore, in equilibrium \( MSC = MSB \), which is the condition for efficiency. Therefore, the equilibrium quantity happens to be efficient. This means social welfare is maximized at \( Q = 8 \). If output were to go up a bit, marginal social cost would exceed marginal social benefit, thus lowering social welfare. If output were to go down a bit, total social benefit would decline by more than total social cost would decline, thus lowering social welfare. So the point where \( MSB = MSC \) maximizes social welfare.

i) Using the efficiency criterion, could the government do any better than the market in allocating goods in this case?

Nope. If the government knew the MSB and MSC curves, it could do as well as the market, but not better. And if it was wrong, it would likely make things worse (from an efficiency perspective).

2) (Using the setup from problem 1) Now suppose there is an externality associated with pizza slices. Consumers of the pizza have a nasty habit of dropping their paper plate on the sidewalk after eating. This presents a form of visual pollution to everyone else in the area.

Assume that, on average, \( \frac{1}{2} \) plate is dropped on the sidewalk per slice of pizza consumed. Each plate on the sidewalk causes $2 of collective unhappiness to society.

a) Is this a positive or a negative externality?

Negative, because it imposes costs on others.
b) Is it a consumption externality or a production externality?

*Consumption, because it is the actions of consumers that have effects on others.*

c) What is the marginal external cost of a slice of pizza?

*On average, 1 slice of pizza is associated with ½ plate dropped. Each plate dropped causes $2 of external damage. Therefore the marginal external cost of each slice of pizza is (1/2)*2=$1.*

d) Draw the marginal social benefit curve.

*To get this, shift down the MPB curve by $1 to reflect the constant MEC=1.*

e) Does equilibrium production of pizza change in the face of the externality.

*No. Private markets ignore externalities. This should change neither consumer nor producer behavior. The equilibrium will be at (Q,P)=(8,4)*

f) Calculate the total external cost of pizza consumption in equilibrium.

*TEC is $1 per slice for 8 slices consumed. So TEC=$8. It’s the area between MSB and MPB from Q=0 to Q=8.*

g) Calculate the total social benefit of pizza consumption in equilibrium.
**TSB=TPB-TEC.** Graphically it is the area under the MSB curve up to \( Q=8 \). A trapezoid with base 8 and average height 4. So TSB=$32.

h) Calculate total welfare in equilibrium.

\[ SW = TSB - TVC = 32 - 16 = \$16 \]

i) What is the efficient level of pizza production, in light of the externality?

*Efficient \( Q \) is where MSC=MSB.*

\[ MSB = 5 - (1/4)Q \]
\[ MSC = (1/2)Q \]

Setting these equal gives \( 5 - (1/4)Q = (1/2)Q \), or \( 5 = (3/4)Q \), so \( Q = 20/3 \)

j) How much would total social benefit decline by moving to that efficient level?

*Oops. Thought I’d picked numbers that worked out well. Doesn’t look that way now...my apologies! Still, if you’ve got the graphical intuition, this isn’t too hard.*

Social benefit declines by a trapezoid of width \( 8 - (20/3) \), or \( 4/3 \), and average height of \( 19/6 \). To get the average height, look at MSB where \( Q=8 \): MSB=3 there. Then look at MSB where \( Q=20/3 \) (the efficient quantity). MSB=10/3 there. The average of 3 and 10/3 is \( 19/6 \).

So social benefit declines by \( (4/3) \times (19/6) = 38/9 \)

k) How much would total social cost decline by moving to that efficient level?

*Social cost falls by a slightly larger trapezoid, bounded by \( Q=8 \), \( Q=20/3 \) and the MSC curve. Again, this has width \( 4/3 \). The average height is \( 11/3 \) (average of 4 and 10/3). So this trapezoid has area \( 44/9 \).*

Social cost declines by \( 44/9 \).

l) What would total social welfare be at the efficient level? Compare that with total social welfare in equilibrium.

*Social welfare in equilibrium is \$16 or \$48/3. At the efficient level of pizza consumption, SW is \$50/3.*

\[ SW = TSB - TVC \]

\[ TVC = 20/3 \times 10/3 \times 1/2 = 200/18 \]
\[ TSB = 20/3 \times [(15/3+10/3) \times (1/2)] = (20/3) \times 25/6 = 500/18 \]
$SW=300/18=\$50/3$

m) What is the deadweight loss associated with the pizza market?

$DWL=\$(2/3)$

n) What are some policy instruments the government could use to eliminate the deadweight loss?

The government could tax pizza, it could pay people a reward to use trashcans, it could impose a quota on pizza consumption, or set a price control that would induce the efficient quantity. Try drawing each of these cases for practice.

3) Now suppose the externality occurs in the following form. The consumers don’t dump their plates on the ground. Instead, the pizza parlors dump their trash (tomato cans, cheese wrappers, etc.) on the street at the end of the day. How would your analysis differ from in problem 2? Which curve would you alter now, to reflect the externality. Supposing the marginal external cost is the same per slice as above, does the efficient equilibrium differ?

Now we’re talking about a production externality. If we assume the same MEC associated with littering by the owner, we’ll now shift the MPC curve up by $\$1$ to reflect the externality. Notice that if you work through this, shifting the MPC up vertically by $\$1$ yields the same efficient quantity as shifting the MPB down vertically by $\$1$. This points to the fact that if you’re not sure about whether to count something as a production or a consumption externality, just pick one and move forward with the analysis. It will yield the same efficient quantity.

4) (Using setup from problem 2) Suppose the Victoria town council wants to apply a tax on pizza, in order to induce the efficient level of pizza consumption.

a) Suppose the tax will be imposed on consumers. That is, each consumer must pay amount $t$ per slice of pizza they buy. Draw a picture showing how the tax affects the marginal private benefit curve.

See below. A $t$ per slice tax on consumers shifts the demand curve down vertically by $t$. You can think of the tax as reducing consumers’ willingness to pay for each slice by the $t$ they have to hand over to the government.

b) What is the level of tax (per slice) that should be chosen in order to induce an efficient equilibrium?

A tax of $\$1$ per slice will induce the efficient equilibrium. By setting the tax equal to the MEC, consumers are forced to internalize the externality. They still don’t care about the damage their litter causes, but they now take into account the extra $\$1$ cost associated with a slice of pizza (due to the tax).
c) What is the new equilibrium quantity? Price paid by consumers? Price received by producers?

New equilibrium occurs where MPB(w/tax) = MSC. MPB(w/tax) = 5 - (1/4)Q. MSC = (1/2)Q. So the equilibrium Q (w/tax) is 20/3. Consumers pay producers \( P_s = \frac{10}{3} \) per slice in equilibrium. Consumers also pay the government $1, so \( P_c = \frac{13}{3} \).

Now suppose the tax will be imposed on producers of pizza instead of on consumers. That is, for each slice produced, the pizza parlor must pay $t.

d) What is the level of tax (per slice) that will induce efficiency?

*It doesn’t matter who pays the tax in the administrative sense of who gives the money to the government. Result will be the same. Redo the analysis by shifting up the MPC curve by $1, to reflect higher marginal cost to suppliers. Here, the tax induces the suppliers to take into account the extra dollar cost associated with each slice (they may not care about the littering, but they care about the tax and so act as if they care about the littering). A $1 per slice tax levied on producers will have exactly the same result as a $1 per slice tax levied on consumers. Producer and consumer prices will be the same, as will equilibrium quantity under the tax (which will be efficient).*

e) What is the new equilibrium quantity? Price paid by consumers? Price received by producers?

\[ Q' = \frac{20}{3} \]
\[ P_c = \frac{13}{3} \]
\[ P_s = \frac{10}{3} \]

f) Calculate total social welfare (consumer surplus + producer surplus + government revenue – total external cost).
5) (new question—not about pizza) Describe how each of the following policies could be used to address a negative production externality. Your answers should include a picture. In each case, discuss the social welfare implications of the policy change. Also discuss the distributional impacts (i.e. which policies are better for producers, and which are better for consumers?). In each case, carefully label areas showing how social welfare changes for different groups, when the policy is implemented.

a) A production quota (a quota is a maximum allowable production limit set by the government).

A production quota, if set at the efficient level of production, would prevent too much of the good from being produced. This is one way the government could induce efficient production. In the diagram below, note that the quota pushes the price of the good up, which benefits producers at the expense of consumers. Distributionally, the quota is good for the producers, if the producers are granted the right to produce by the government (as opposed to having to pay for the right to produce...in which case the government could seize some of producer surplus as government revenue by auctioning quota rights to the highest bidder).

b) A binding price ceiling.
A binding price ceiling is a price ceiling set below the equilibrium price. If the right price were chosen, producers would be induced to lower their output to the efficient level. Those consumers are able to obtain the product at this lower price would get lots of consumer surplus. Distributionally, this solution favors consumers.

\[ Q_{eff} = Q_{pf} \]

**MSC**

\[ MPC = S \]

**Price Ceiling**

\[ \$ \]

\[ P \]

\[ Q \]

\[ CS \text{ w/price ceiling} \]

\[ PS \text{ w/price ceiling} \]

**c) A binding price floor.**

A binding price floor is a price floor set above the equilibrium price. If the right price floor were chosen, consumers would be induced to lower their quantity demanded to the efficient level. Those producers who produce the product would earn the high price set by the floor. Distributionally, this solution favors firms. Note that it is equivalent to the quota (when quota rights are given to the producers).

\[ Q_{eff} = Q_{pf} \]

**MSC**

\[ MPC = S \]

**Price Floor**

\[ \$ \]

\[ P \]

\[ Q \]

\[ CS \text{ w/price floor} \]

\[ PS \text{ w/price floor} \]

6) Explain, using a diagram in each case, why the above policies would not work to correct for a positive externality. What would be a more useful policy?
The problem with a positive externality is that too little of the good gets produced in equilibrium. So, effective policies to correct the situation must increase production of the good. A quota, to the extent that it places a maximum limit on production (but no minimum limit), will not cause production to increase beyond the equilibrium level. A binding price ceiling will not work, because while it induces consumers to want to buy more of the good, it induces producers to produce less (as in 1b above). A binding price floor will not work, because while it induces producers to want to make more of the good, it induces consumers to demand less (as in 1c above). Producers don’t want to make stuff that will get thrown out, so the lower quantity demanded of consumers determines total output.

A more useful policy would be something that increases output. A natural option is a subsidy. The government could offer producers a per unit subsidy that would lead to the efficient level of production. Perfectly analogous to the per unit tax with a negative externality, a per unit subsidy with a positive externality involves setting the subsidy equal to the marginal external benefit at the efficient level of production. See the diagram below for an illustration.

7) Adam owns a 10 acre apple orchard. His neighbor, Eve, runs an apiary (she keeps bees to make honey). Each hive of bees can pollinate $\frac{1}{2}$ acre of apples, thereby raising the value of Adam’s apple production by $10. The honey produced by one hive is worth $100 and Eve’s marginal costs are given by $MC=10+5q$, where $q$ is the number of hives she chooses to use. Assume that both Adam and Eve are operating in perfectly competitive industries. No one else is affected by Eve’s bees.

a) What is the equilibrium number of hives that Eve will employ?

Eve will set $MR=MC$ (like any profit maximizing firm). Since she’s a competitive producer, $MR=P$. So she sets $100=10+5q$, and so chooses $q=18$. 
b) Why is this amount not efficient?

The marginal social cost of an extra hive is $100 (Eve’s MPC) minus the $10 boost it gives to Adam’s apple production (we can think of this as raising the value of Adam’s production, or lowering his cost of production). Thus MSC=MPC-MEB, or MSC=100-10=90. If MSB=100>90=MSC, then MSB>MSC, so more hives should be employed.

c) At the equilibrium quantity, what is the maximum that Adam would be willing to pay to induce Eve to employ 1 extra hive?

Adam gets $10 of benefit (or cost reduction) per hive that Eve employs, up to the point where all of his trees are pollinated. Until all his trees are pollinated he’d be willing to pay up to $10 per hive to induce Eve to employ more hives.

d) What is the minimum that Eve would be willing to accept to increase her employment of hives by 1?

She needs to cover her MC in order to be willing to employ another hive. MC of the 19th hive will be $105. So she needs to receive at least this much to employ the extra hive. The honey it produces is worth $100, so she needs at least $5 from Adam, in order to induce her to employ the 19th hive. The marginal cost of the 20th hive is $110. So Adam would need to pay her $10 for the 20th hive.

As it turns out the 20th hive would make Adam’s orchard fully pollinated. Note that from here on, his willingness to pay Eve goes to zero. Suppose, however, that he had an extra ½ acre that still needed pollinating (this would increase its output by a value of $10). Would Adam induce Eve to install an extra hive? The answer is no. The marginal cost of the 21st hive would be $115. The MR it brings in is $100, which means Adam would have to pay Eve at least $15 to induce her to employ the 21st hive. It’s not worth it for him to pay this much, since the hive would only add $10 to his revenues. Hence, he’d stop paying Eve at the 20th hive, even if he had acreage left unpollinated.

e) What is the efficient number of hives? Remember that Adam has a 10 acre farm.

20 hives.

f) What does the Coase Theorem say about Adam and Eve’s problem?

This is a situation where the Coase Theorem is highly applicable, as the example illustrates. Adam and Eve could work this arrangement out over their morning jog together (i.e. bargaining costs are low) and Adam could easily observe (by counting) the number of hives Eve was employing (monitoring costs are low).

8) Suppose the demand curve in a market is given by Q=300-2P. Supply is given by Q=P. Suppose also that each unit consumed of this good produces an externality worth $30 to people nearby (imagine it smells good).
a) What are the equilibrium quantity and price in this market assuming no government intervention?

Equilibrium occurs where quantity supplied equals quantity demanded. This is where \( P = 300 - 2P \). \( 3P = 300 \), or, in equilibrium, \( P = 100 \). Since \( Q = P \), equilibrium \( Q \) is 100 as well.

\( (P,Q) = (100, 100) \) in equilibrium.

b) What is the efficient quantity in this market?

To find this, we need to come up with equations for the MSB and MSC curves. Since this externality comes from consumption, we’ll show the externality on the MB side of the market.

We can get marginal private benefit from the inverse demand curve. Demand is given by \( Q = 300 - 2P \). Inverse demand is therefore \( P = 150 - (1/2)Q \). Since we also measure marginal benefit on the y-axis, we can write marginal private benefit as \( MPB = 150 - (1/2)Q \). If the externality is $30 per unit, this means the MSB curve is just the MPB curve shifted up by $30. So \( MSB = 180 - (1/2)Q \).

We measure marginal cost on the y-axis as well, so we can write marginal private cost as \( MPC = Q \). Since we’re showing the externality on the consumption side, \( MSC = MPC = Q \).

Setting \( MSC = MSB \) (the condition for efficiency), we get

\[
Q = 180 - (1/2)Q \\
(3/2)Q = 180 \\
Q = 120
\]

Thus, 120 is the efficient quantity. The diagram below illustrates.
c) What is the deadweight loss in this market at the equilibrium?

*The deadweight loss is the shaded triangle in the diagram above. As always, it’s the area bounded by MSB, MSC, and the efficient and equilibrium quantities. Note that while the two small triangles making up DWL look to be of equal size they are not. The upper triangle has an area of 100. The lower triangle has an area of 200. This gives a total deadweight loss of $300.*

d) What policies could be used to achieve this efficient quantity?

*The government could force industry to produce 120 units. But that’s a bit of a blunt policy instrument. A preferable policy would be a subsidy to increase output.*

e) What per unit subsidy would induce the efficient quantity? Illustrate this subsidy in a diagram.
A subsidy equal to marginal external cost at the efficient quantity would do the trick. Note that MEC is always $30 in this problem. So the optimal subsidy will be a $30 per unit subsidy.

We can subsidize consumers or producers. A result that we’ll see when we study tax is that it doesn’t matter whether we subsidize consumers or producers—the overall effect will be the same. I’ll subsidize producers in this case (work through the case of subsidizing consumers—you should get the same answer that I get).

The subsidy will shift down the MPC curve by the amount of the subsidy. You can see this in the diagram below. Note that the quantity $Q=120$ is produced when the subsidy is $30$ per unit.

f) What is the change in welfare that results from imposing the optimal subsidy?

Society recovers the deadweight loss that existed in the free-market equilibrium. That is, social welfare rises by $300$. 
Another way to find this is to find \((CS+PS+TEB)-(\text{Government expenditure})\) after the subsidy is implemented, and subtract \((CS+PS+TEB)-(\text{Government expenditure})\) before the subsidy is implemented. Draw the relevant areas to assist you in doing this calculation.

Yet another way to find this is to figure out the gain in total social benefits moving from \(Q=100\) to \(Q=120\) minus the increase in total costs moving from \(Q=100\) to \(Q=120\). Again, draw the relevant areas to assist you in your calculation.

9) Suppose that monuments are public goods. Suppose there are two types of people in the economy, each type with a different individual marginal benefit curve.

A) Monument lovers: \(MB=10-2Q\)
B) Others \(MB=3-Q\).

There are 5 people of each type in the economy.

a) Find the overall MB curve for “monument lovers.”

We want to vertically aggregate the demand curves. They need to be in the form \(MB=P=a-bQ\) to add them up (they’re already in this form). Note that if you were horizontally aggregating, you’d need to put them in the form \(Q=c-dP\)

\(MB_I=50-10Q\)

b) Find the overall MB curve for “others.”

\(MB_o=15-5Q\)

c) Find the overall MB curve for everyone. Draw the curve. Carefully label axes at any kinks and intercepts.

\[\text{The equation for the overall MB curve is } MSB=65-15Q. \text{ You get this by vertically aggregating the two “total” MB curves for the two types. Notice that once } Q=3, \text{ the MB}\]
for “other” types is zero. So from this point on, giving them more of the public good does nothing for total benefit. But giving more to the monument lovers still adds to total benefit.

So technically the over MB curve is

\[ MSB = 65 - 15Q \text{ for } 0 \leq Q \leq 3 \]
\[ = 50 - 10Q \text{ for } 3 < Q \leq 5 \]

It’s piecewise linear.

d) Suppose monuments are produced at a constant marginal cost of $10. What is the efficient level of monument production?

We have efficient production where MSC=MSB. So set 10=MSB in the relevant range. Note that we’re on the part of the MSB curve where MSB=50-10Q, so we want to set MSC=10=50-10Q, or Q=4.

e) What is total social welfare at the efficient level of production?

\[
TSB = $142.50 \text{ (to get this, find area of trapezoid from } Q=0 \text{ to } Q=3, \text{ add it to area of trapezoid from } Q=3 \text{ to } Q=4) \\
TVC = $40 \text{ (4 monuments at constant marginal cost of }$10) \\
SW = TSB - TVC = $102.50
\]

f) Do you expect that the efficient level will be achieved in equilibrium? Why or why not?

No, because people will have a tendency to free ride. Some form of intervention will likely be required to achieve efficient provision.

g) Suppose the marginal cost of production is $50. Now what is the efficient level of monument production?

\[
MSC = MSB \text{ (for efficiency)} \\
50 = 65 - 15Q \text{ so } Q_{\text{eff}} = 1
\]

10) There are three firms in a community that pollute the environment. The government has decided that 18 units of pollution must be abated. The marginal cost of pollution abatement for each firm is given in the table below. Assume that each firm would pollute 10 units if unregulated.

<table>
<thead>
<tr>
<th>Unit abated</th>
<th>Firm A</th>
<th>Firm B</th>
<th>Firm C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</table>
a) The government mandates that each firm must cut pollution by 6 units. Is this solution cost efficient? Explain why or why not.

This solution is not cost efficient. To see why, first look at the cost of each firm abating 6 units.

<table>
<thead>
<tr>
<th>Unit abated</th>
<th>Firm A</th>
<th>Firm B</th>
<th>Firm C</th>
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<tbody>
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<td>18</td>
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</table>

Abatement cost per firm 28 42 63

Total cost of abating 18 units of pollution if every firms cuts pollution by 6 units = 28+42+63 = 133.

The cost of abating the 6th unit of pollution is not the same for the three firms. It is cheaper for firm A ($10) than for Firm B ($12) and firm C ($18). By reallocating units of abatement among firms we can save costs. Since it is cheaper for firm A to abate the 7th unit ($11) than it is for firm C to abate the 6th unit ($18), we can save costs if firm A would abate one more unit and firm C would abate one unit less. The last three units abated cost 10+12+18 =40 with 6 units abated by each firm. If, instead, we have firm A abate 7 units, firm B abate 6 units, and firm C abate 5 units, total abatement remains at 18 units, but the cost of the last three units abated is 11+12+15=38, and the total cost of abating 18 units is 39+42+45=126. Since, under this reallocation of abatement responsibility, the same amount of pollution is abated, but at lower cost, this shows that having each firm abate 6 units is not cost efficient.

b) If the solution in a) is not cost efficient, how much pollution should each firm produce at the cost efficient outcome?

Given a pollution abatement target, each firm should abate so that cost of abating the last unit of pollution is the same for all firms. As we have seen from the answer to a), if firm A abates one more unit and firm C abates one unit less, costs of abating decrease. We can make the same argument to have firm A abate 8 units and have firm C abate only 4 units. So if firm A abates 8 units, firm B abates 6 units and firm C abates 4 units, every firm abates up to the point where their MC of abating is the same. Total cost of abating is then
<table>
<thead>
<tr>
<th>Unit abated</th>
<th>Firm A</th>
<th>Firm B</th>
<th>Firm C</th>
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<td>8</td>
<td>12</td>
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</tbody>
</table>

**Abatement cost per firm**

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<thead>
<tr>
<th></th>
<th>Firm A</th>
<th>Firm B</th>
<th>Firm C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total cost of abating</strong></td>
<td>$51</td>
<td>$42</td>
<td>$30</td>
</tr>
</tbody>
</table>

Suppose the government auctions pollution permits using a second price auction. (that is, the highest bidder receives the permit at a price equal to the second highest bid). Without any pollution permits, each firm must abate all of its pollution, that is 10 units. It is a well-established economic result, that in second price auctions, people are best off if they bid equal to their true willingness to pay. That is, if for example firm A must abate 10 units but now has an option to get a pollution permit, this permit is worth to firm A $25, because this is exactly how much firm A would save by having to abate one unit of pollution less. So firm A would bid $25 in order to get its first pollution permit. Note that sometimes two firms are the highest bidders. In this case only one firm can receive the permit. To break the tie, give the permit to the firm whose name appears first in the alphabet.

c) Write down in the table below the bids of each firm for each of the 12 pollution permits.

<table>
<thead>
<tr>
<th>Permit</th>
<th>Firm A’s bid</th>
<th>Firm B’s bid</th>
<th>Firm C’s bid</th>
<th>Winner</th>
<th>Price paid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>25</td>
<td>20</td>
<td>30</td>
<td>Firm C</td>
<td>25</td>
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<tr>
<td>2nd</td>
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<td>Firm C</td>
<td>25</td>
</tr>
<tr>
<td>3rd</td>
<td>25</td>
<td>20</td>
<td>24</td>
<td>Firm A</td>
<td>24</td>
</tr>
<tr>
<td>4th</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>Firm C</td>
<td>20</td>
</tr>
<tr>
<td>5th</td>
<td>16</td>
<td>20</td>
<td>21</td>
<td>Firm C</td>
<td>20</td>
</tr>
<tr>
<td>6th</td>
<td>16</td>
<td>20</td>
<td>18</td>
<td>Firm B</td>
<td>18</td>
</tr>
<tr>
<td>7th</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>Firm B</td>
<td>16</td>
</tr>
<tr>
<td>8th</td>
<td>16</td>
<td>16</td>
<td>18</td>
<td>Firm C</td>
<td>16</td>
</tr>
<tr>
<td>9th</td>
<td>16</td>
<td>16</td>
<td>15</td>
<td>Firm A</td>
<td>15</td>
</tr>
<tr>
<td>10th</td>
<td>12</td>
<td>16</td>
<td>15</td>
<td>Firm B</td>
<td>15</td>
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<tr>
<td>11th</td>
<td>12</td>
<td>14</td>
<td>15</td>
<td>Firm C</td>
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<tr>
<td>12th</td>
<td>12</td>
<td>14</td>
<td>12</td>
<td>Firm B</td>
<td>12</td>
</tr>
</tbody>
</table>

Explanation of table entries: Without a permit, a firm needs to abate 10 units of pollution. With one permit it needs to abate 9 units of pollution. So how much is it worth to the firm to receive one permit? It’s equal to cost savings of not having to abate the 10th unit of pollution. Thus when the government auctions off the first permit, firms’ bids
equal their MC of abating the $10^{th}$ unit of pollution. Once a firm has purchased a permit, it values another permit equal to the cost savings of not having to abate the $9^{th}$ unit of pollution, and so on and so forth.

Note that sometimes two firms are the highest bidders. In this case only one firm can receive the permit and I have given the permit to the firm whose name appears first in the alphabet. If you give the permit to the other firm, nothing changes in terms of overall costs of the firms. Here is what happens if you break the ties differently:

<table>
<thead>
<tr>
<th>Permit</th>
<th>Firm A’s bid</th>
<th>Firm B’s bid</th>
<th>Firm C’s bid</th>
<th>Winner</th>
<th>Price paid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1\text{st}</td>
<td>25</td>
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<td>Firm B</td>
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</table>

d) How many units does each firm abate and how many permits does each firm buy?

Firm A buys 2 permits and abates 8 units of pollution, firm B buys 4 permits and abates 6 units of pollution, firm C buys 6 permits and abates 4 units of pollution.

e) What is government revenue from this auction?

Government receives $25+25+24+20+20+18+16+16+15+15+14+12 = 220$

f) What are the cost savings to society from this policy compared to a)? (Subtract government revenue from costs of firms and compare with costs of firms under a)!

With permits: The cost of permits to firms is equal to what the government receives in revenues and hence the permit costs to firms and government revenues cancel out. This means, the social cost of abating with permits is equal to the cost of firms abating 18 units of pollution.

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</table>
Social cost of abating 18 units of pollution with permits is equal to \(51 + 42 + 30 = 123\). This amount is $10 less than in a). It is also equal to the cost efficient amount found in b). Auctioning permits is cost efficient.