ARE 336 – Midterm exam– Fall 2025

October 8, 2025

You have until the end of class to work on the exam. You may use one sheet of notes for this exam. **If you answer 'False' for any True/False questions, you must provide an explanation for full credit**. Please draw a box around your final answer to each numeric question. Partial credit may be given if you include your work.

This exam has 15 questions, for a total of 100 points (with the possibility to earn up to 5 bonus points).

1. [2 points] **T** In a competitive market for private goods, a tax on producers results in the same equilibrium quantity as a tax on consumers.

   Solution: We have seen this in class.

2. [2 points] **T** According to scientific consensus, climate change is caused by the "greenhouse effect."

   Solution: We have gone over this in class.

3. [2 points] **F** Correlation necessarily implies causation.

   Solution: Correlation does not imply causation!

4. [2 points] **T** Imposing a tax on a perfectly competitive market creates deadweight loss.

   Solution: We have gone over this in class.

5. [2 points] **F** The efficient quantity of emissions in the emissions regulation model is always complete abatement.

   Solution: This will often not be the case. The marginal cost of abatement is often increasing in the quantity of emissions abated, and the marginal external damages is often decreasing in the quantity of emissions abated. Thus, we usually get to a point where the cost to abatement one more unit outweighs the external damages avoided.

6. [3 points] Which of the following will *for sure* cause a decreased price?
   A. Increase in demand
   B. Increase in supply
   C. Decrease in demand and increase in supply
   D. Decrease in demand and decrease in supply
   E. None of these will *for sure* cause a decreased price

7. [3 points] Select all of the following statements which are *normative*?
   A. We should subsidize green energy.
   B. Taxing consumers will decrease the quantity consumed.
   C. Taxing producers is better than taxing consumers.
   D. Theoretical models without empirical validation are useless.
   E. Theoretical models lead to conclusions.

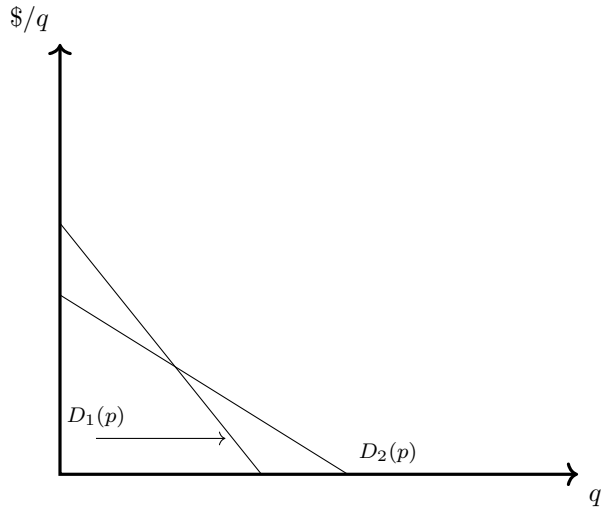
8. [3 points] Which of these is NOT a solution to market failure that we have talked about in class?
   A. Implement a tax.
   B. Allow for Coasian bargaining.
   C. Cap-and-trade.
   D. Ignore the market failure.

9. [3 points] Which of these historical figures have we NOT talked about in class?
   A. John Nash
   B. Ellinor Ostrom
   C. Garrett Hardin
   D. Ronald Coase
   E. Arthur Pigou

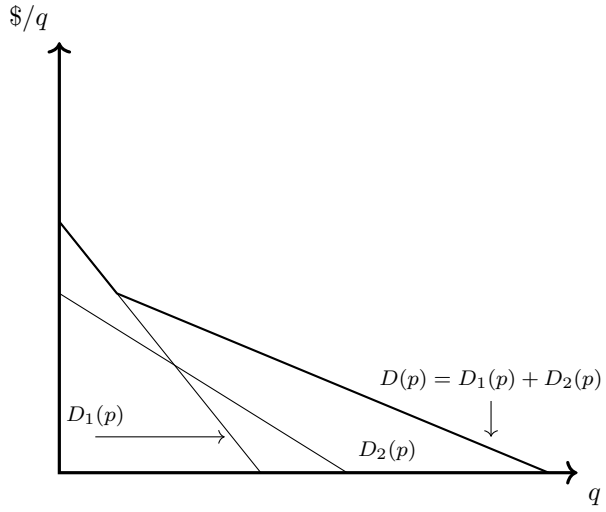
   (a) [2 ½ bonus points] Which of these wrote *The Tragedy of the Commons*?

10. [3 points] Select all of the following which represent an externality?
    A. Lost profits due to a neighbor's pollution.
    B. Boycotting a store because it polluted a local lake.
    C. Damages to health from a factory's pollution.
    D. Yellowstone National Park raising money to repair a bridge.
    E. A surge in economic activity in areas surrounding Yellowston National Park after it completes repairs on a broken bridge.

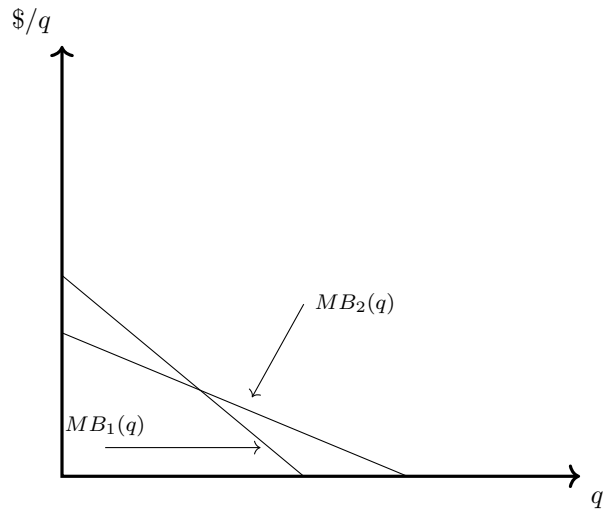
11. [2 ½ points] On the graph below, show what it means to horizontally sum two demand curves.



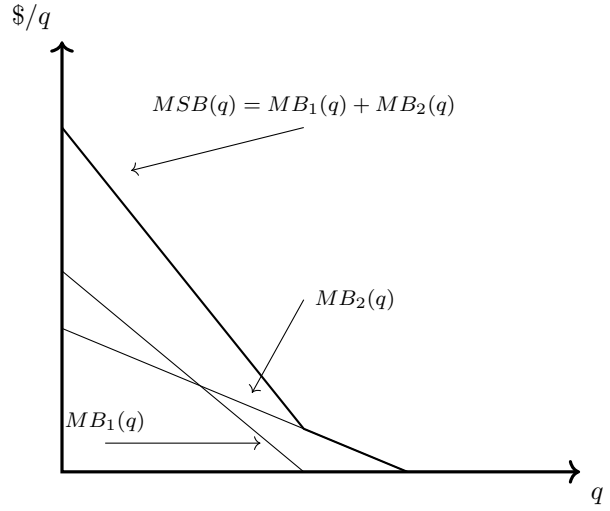
Solution:



12. [2 ½ points] On the graph below, show what it means to vertically sum two marginal benefit curves.



Solution:



13. Consider the demand given by $Q_d = 30 - 2p$ and supply given by $Q_s = p - 3$.

    (a) [5 points] What is the equilibrium price?

Solution: The equilibrium price is the price that equates Q_d and Q_s:

$$\begin{aligned} Q_d(p^*) &= Q_s(p^*) \\ 30 - 2p^* &= p^* - 3 \\ 3p^* &= 33 \\ p^* &= 11 \end{aligned}$$

(b) [5 points] What is the equilibrium quantity?

Solution: The equilibrium quantity can be found by putting p^* into either Q_d or Q_s. Observe:

$$q^* = Q_d(p^*) = 30 - 2 \cdot p^* = 30 - 2 \cdot 11 = 8$$

and

$$q^* = Q_s(p^*) = p^* + 3 = 11 - 3 = 8$$

(c) [2 ½ points] What are the inverse demand and inverse supply functions?

Solution: The inverse demand and inverse supply functions can be found by "solving" Q_d and Q_s, respectively, for p. Observe:

$$\begin{aligned} q &= 30 - 2P_d(q) \\ 2P_d(q) &= 30 - q \\ P_d(q) &= 15 - \frac{1}{2}q \end{aligned}$$

and

$$\begin{aligned} q &= P_s(q) - 3 \\ P_s(q) &= q + 3 \end{aligned}$$

(d) [5 points] Calculate the consumer surplus at the equilibrium?

Solution: The consumer surplus is the area below the demand curve and above the equilibrium price:

$$\begin{aligned} CS &= \frac{1}{2} \cdot (\$15 - \$11) \cdot 8 \\ &= \$4 \cdot 4 \\ &= \$16 \end{aligned}$$

(e) [5 points] Calculate the producer surplus at the equilibrium?

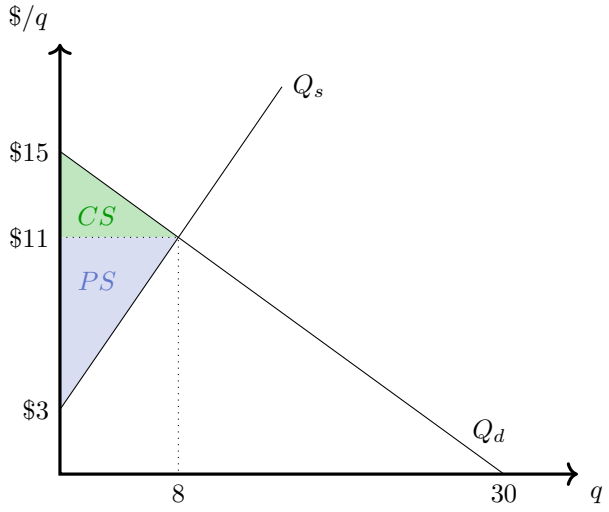
Solution: The producer surplus is the area below the equilibrium price and above the

supply curve:

$$\begin{aligned} PS &= \frac{1}{2} \cdot (\$11 - \$3) \cdot 8 \\ &= \$8 \cdot 4 \\ &= \$32 \end{aligned}$$

(f) [5 points] Draw this market. Make sure you label the supply, demand, equilibrium price, equilibrium quantity, choke prices for demand and supply, consumer surplus, and producer surplus. All prices and quantities should be labeled with their numeric value.

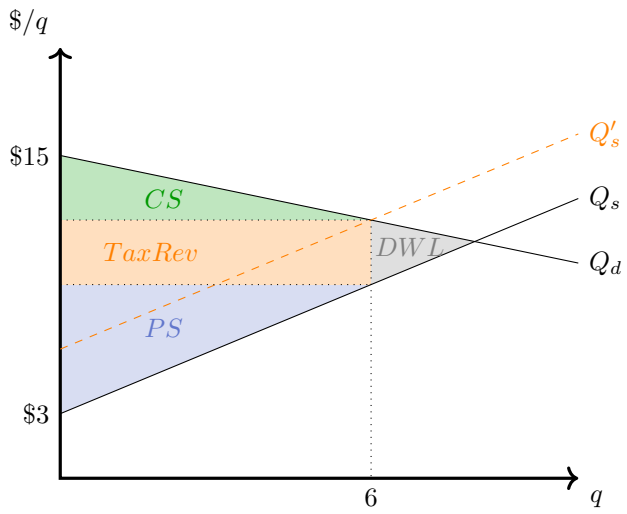
Solution:



(g) Now consider a $3 tax on producers. Answer the following:

i. [5 points] What is the new equilibrium quantity?

Solution:



The new effective supply curve is the inverse supply plus the \$3 tax:

$$P_s^\tau(q) = P_s(q) + 3 = 6 + q$$

The new equilibrium quantity equates this with the demand function:

$$\begin{aligned} P_d(q^\tau) &= P_s^\tau(q^\tau) \\ 15 - \frac{1}{2}q^\tau &= 6 + q^\tau \\ \frac{3}{2}q^\tau &= 9 \\ q^\tau &= 6 \end{aligned}$$

ii. [2 ½ points] What is the *effective price* that is used in calculating producer surplus?
(**Hint:** The effective price is the price that the suppliers take home after taxes as revenue.)

Solution: This is the price that will induce the suppliers to provide q^{**} units of the good:

$$\begin{aligned} p_e &= P_s(q^\tau) \\ &= 3 + q^\tau \\ &= 3 + 6 \\ &= \$9 \end{aligned}$$

iii. [2 ½ points] What is the *market price* that consumers pay?
(**Hint:** The market price is the sum of the effective price and the tax.)

Solution: The market price is the price that the consumers pay:

$$p_m = p_e + \$3 = \$9 + \$3 = \$12.$$

iv. [5 points] How much tax revenue is collected?

Solution: The equilibrium quantity yin the post-tax market is 6, and each unit earns \$3 in tax revenue. The total tax revenue is

$$TaxRev = \$3 \cdot 6 = \$18.$$

v. [5 points] How much deadweight loss is there?

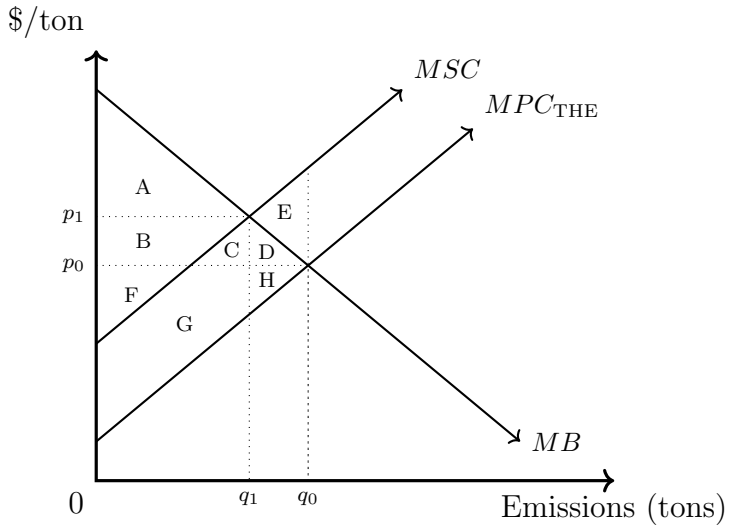
Solution: The deadweight loss is the total surplus that is neither accrued to the consumer or producer nor transferred as tax revenue:

$$\begin{aligned} DWL &= \frac{1}{2} \cdot \underbrace{(p_m - p_e)}_{=\tau=\$3} \cdot (q^* - q^\tau) \\ &= \frac{1}{2} \cdot \$3 \cdot (8 - 6) \\ &= \$3 \end{aligned}$$

Question 13: 47½ points

14. Consider the case of Tar Heel Electric (THE), an energy plant which is situated across a valley from Wolfpack Winery and Vineyard (WWV). THE collects revenue by generating electricity through a process which pollutes the local air. Local air pollution decreases the enjoyment of visitors to WWV and can also affect the taste of its grapes. THE was here first, so they have the "right to pollute" without internalizing the externality it creates via lost profit to WWV.

    This market is shown in the graph below where MB represents the marginal benefit of all electricity users, MPC_{THE} is the marginal private cost of producing electricity, and MSC is the marginal privat cost of producing electricity *plus* the marginal external damages to WWV:



(a) [5 points] Given that THE has the right to pollute, what is the baseline level of emissions?

Solution: The baseline level of emissions is q_0.

(b) [5 points] Is the baseline quantity of emissions socially optimal? Why or why not? If not, what is?

Solution: The optimal level of emissions is the level where the marginal social cost equals the marginal benefit. That is q_1.

(c) [2 ½ points] Using the letters marked in the graph, what is the consumer surplus, the producer surplus collected by THE, and the lost profits (externality) suffered by WWV at the baseline?

Solution:

Consumer surplus	A + B + C + D
Producer surplus	F + G + H
Lost profits by WWV	G + C + H + D + E

(d) [2 ½ points] Assuming the baseline quantity of emissions is not socially optimal, how much would WWV be willing to pay THE to produce the optimal level of emissions? Use the letters to refer to parts of the graph).

Solution: WWV earns E + D + H in additional profit when THE decreases its emissions from q_0 to q_1. This is the maximum WWV is willing to pay for THE to decrease its emissions to the socially optimal.

Question 14: 15 points

15. Marcie and John are roommates. John loves listening to his favorite band, Creed, really loudly on his house speakers (and singing). John's marginal value of listening to Creed is

$$MV(H_l, H_q) = 11 - \frac{1}{2}H_l - H_q$$

where H_l and H_q are the number of hours spent listening to music at a loud volume and a quiet volume, respectively. The loud music hurts Marcie's serenity, and she would be happier if he played his music at a quieter volume. Unfortunately, there are only 8 hours in the day that John can listen to Creed (Marcie is home for all 8 hours).

(**Hint:** The time constraint means we can write $H_q = 8 - H_l$, so we only really need to choose the number of hours he spends listening loudly.)

(a) [2 ½ points] Realizing that $H_q = 8 - H_l$, write John's marginal value MV as a function of just the number of hours he spends listening to music loudly.

Solution: We can "simplify" John's marginal value to be a function of just one variable (here, H_l) by substituting $H_q = 8 - H_l$. Observe:

$$\begin{aligned} MV(H_l) &= MV(H_l, 8 - H_l) \\ &= 11 - \frac{1}{2}H_l - (8 - H_l) \\ &= 11 - 8 - \frac{1}{2}H_l + H_l \\ &= 3 + \frac{1}{2}H_l \end{aligned}$$

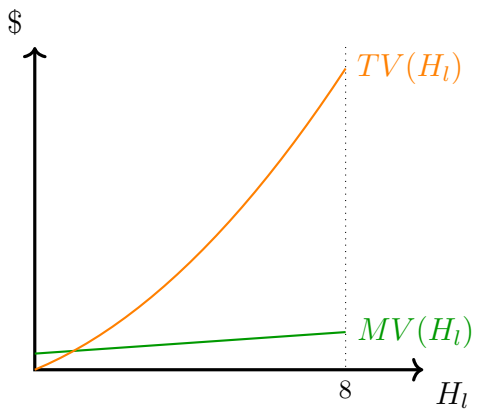
(b) [2 ½ points] If John ignores Marcie's serenity, how many hours will he spend listening to music loudly? Call this quantity H_l^*. Using the fact that $H_l^* + H_q^* = 8$, how many hours will his spend listening to his music quietly?

(**Hint:** Remember his marginal cost is 0 when he ignores the externality his listening creates.)

Solution: John's goal is to choose H_l that will maximize his *total value*, which is marginal value times the length of time spent listening. Intuitively, because his marginal value is increasing in H_l, we expect him to spend all of his time listening to Creed loudly. But we want to show this a little more rigorously. John's total value is necessarily

$$\begin{aligned} TV(H_l) &= MV(H_l) \cdot (H_l + H_q) \\ &= MV(H_l) \cdot (H_l + 8 - H_l) \\ &= MV(H_l) \cdot 8 \end{aligned}$$

We can do this graphically by plotting these as below:



We see that the highest attainable total value for John occurs when he listens to Creed at a loud volume for 8 hours.

Alternatively, we can try looking at this from the other side of things. Namely, find John's marginal value as a function of H_q:

$$\begin{aligned} MV(H_q) &= MV(8 - H_q, H_q) \\ &= 8 - \frac{1}{2}(8 - H_q) - H_q \\ &= 8 - 4 + \frac{1}{2}H_q - H_q \\ &= 4 - \frac{1}{2}H_q \end{aligned}$$

and we see that the marginal value of listening to Creed is *decreasing* in H_q. Then the optimal number of hours John should spend listening quietly must be 0. To see this, assume that he choosee $H_q = 2$. Then, because he spends 8 hours listening to Creed, his total value is $3 \cdot 8 = 16$. But John can be better off by choosing $H_q = 1$, so that his total value is $4.5 \cdot 8 = 28$. And this is true for any $H_q > 0$.

Both of these methods lead us to the conclusion that John's optimal decision is to listen to his music always at a loud volume. Hence, $H_l^* = 8$, which implies that $H_q^* = 0$.

(c) [2 ½ points] Now assume that the marginal external damage created by John's listening is

$$MD(H_l, H_q) = -10 + 2H_l + \frac{1}{2}H_q.$$

What is the socially optimal number of hours that John should listen to his music loudly? Call this H_l^{**}. What is the socially optimal number of hours that John should listen to his music quietly? Call this H_q^{**}.

(**Hint:** Assume that John still spends all 8 hours listening to his music loudly.)

Solution: Because $H_l = 8 - H_1$, we have that

$$\begin{aligned} MD(H_l) &= MD(H_l, 8 - H_l) \\ &= -8H_l + (8 - H_l) \\ &= -8 + 8 + 2H_l - H_l \\ &= H_l \end{aligned}$$

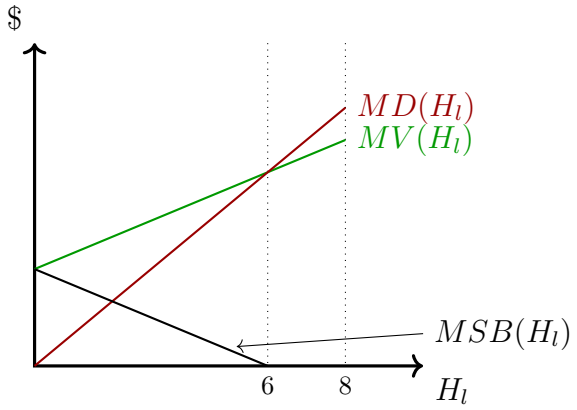
Then the marginal net social benefits is the difference between John's marginal value and Marcie's marginal damage:

$$\begin{aligned} MSB(H_l) &= MV(H_l) - MD(H_l) \\ &= 3 + \frac{1}{2}H_l - H_l \\ &= 3 - \frac{1}{2}H_l \end{aligned}$$

So at the socially optimal number of hours, the marginal benefit will equal the marginal damage (or, equivalently, MSB reaches zero). That is,

$$\begin{aligned} MV(H_l^{**}) &= MD(H_l^{**}) \\ 3 + \frac{1}{2}H_l^{**} &= H_l^{**} \\ \frac{1}{2}H_l^{**} &= 3 \\ H_l^{**} &= 6 \end{aligned}$$

We can see below that the marginal social net benefits reach zero at 6 hours of loud listening, when marginal damage and marginal benefit are equal.



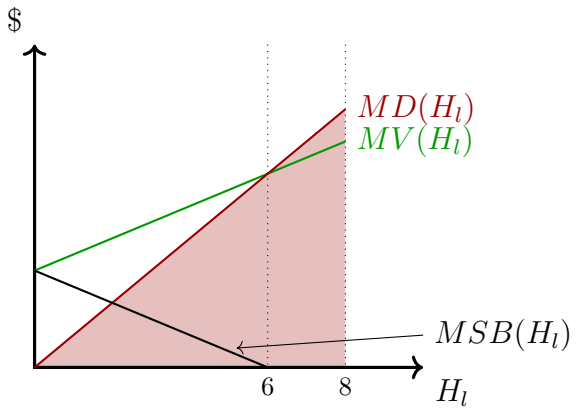
(d) [2 ½ bonus points] Marcie can't stop John from listening to Creed for 8 hours, but she can make an offer to him to induce him to listen to Creed *quietly* for 8 hours (à la Coasian bargaining). How much would Marcie be willing to pay John to decrease the time he spends

listening to music loudly from H_l^{**} to 0?

Solution: If John listens to his music purely at a quiet volume, we will have $H_l = 0$. Marcie will receive the whole area below MD. This is a triangle with area

$$\frac{1}{2} \cdot MD(8) \cdot 8 = \frac{1}{2} \cdot 8 \cdot 8 = 32.$$

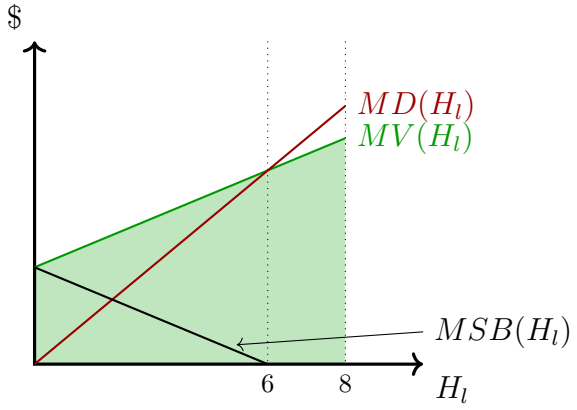
Graphically, she earns the entire red area below:



Will John accept this offer? If he does, he will lose benefits equal to the entire are under his marginal value curve, which is the sum of a rectangle and a triangle:

$$MV(0) \cdot 8 + \frac{1}{2}\left(MV(8) - MV(0)\right) \cdot 8 = 3 \cdot 8 + \frac{1}{2}(7-4) \cdot 8 = 24 + 12 = 36.$$

Graphically, he loses the entire green area below:



Thus, John will not accept this offer.

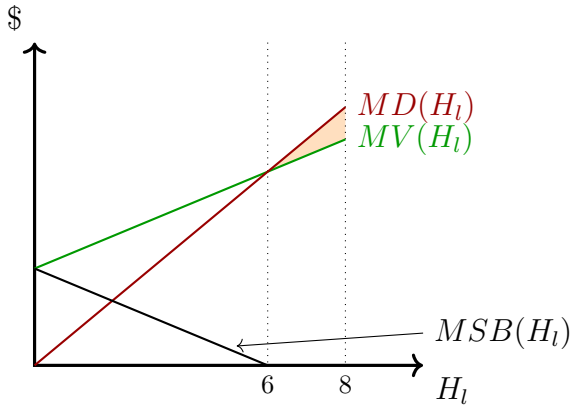
However, Marcie can make him an offer to only listen to Creed loudly for 6 hours. She will earn the entire area under the marginal damage curve between 8 and 6 hours, which is the sum of a rectangle and a triangle:

$$MD(6) \cdot (8-6) + \frac{1}{2}\left(MD(8) - MD(6)\right) \cdot (8-6) = 6 \cdot 2 + \frac{1}{2} \cdot 2 \cdot 2 = 14.$$

John will lose an amount of value equal to the area under the marginal value curve between 8 and 6 hours, which is also the sum of a rectangle and a triange:

$$MV(6) \cdot (8-6) + \frac{1}{2}\left(MV(8) - MV(6)\right) \cdot (8-6) = 6 \cdot 2 + \frac{1}{2} \cdot 1 \cdot 2 = 13.$$

Hence, Marcie's avoided damages will outweigh John's lost value and she can make him some offer x such that $13 \leq x \leq 14$ in exchange for John listening to Creed for 6 hours instead of 8. Graphically, the total net benefit of this process is colored in orange below:



Question 15: 7½ points