

Intermediate Microeconomic Theory

Colin Adams

Florida State University

Summer 2026

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Prologue

This collection contains all materials from my *Intermediate Microeconomic Theory* course, including the syllabus, practice problems, quizzes, and practice exams. Practice problems were distributed as related material was taught. Lecture notes are excluded because they were not shared outside the classroom. Quizzes were given roughly twice a week, except during exam weeks. Answers are provided for all problems except quizzes, as some quiz questions may be reused.

I am grateful to Dr. Yonggyun (YG) Kim and Dr. John R. Hamman for their guidance in preparing me to teach this course. I am especially thankful to the students in the class, whose excitement, thoughtful questions, and constructive feedback not only pushed me to become a better teacher but also made the course a joy to teach.

Last updated: June 22, 2026

ECO 3101: Intermediate Microeconomic Theory

Colin Adams

Summer A, 2026

Course Information

Time:	MoTuWeThFr 9:45PM-11:00AM
Location:	BEL 203
Prerequisites:	ECO 2013, ECO 2023
Credit Hours:	3 hours

Instructor Information

Instructor of Record:	Colin Adams
Email:	cadams5@fsu.edu
Office Hours:	Tu, We, Th at 1:00PM-2:00PM, or by appointment
Office:	Bellamy 291B (by the kitchen)

Prerequisites

Required

- Principles of Macroeconomics (ECO 2013)
- Principles of Microeconomics (ECO 2023)

Recommended

- Proficiency in basic algebra
- Very basic knowledge of Calculus (I will cover all material needed at the beginning of the class)

Course Description

This course is designed to introduce you to formal microeconomic models and enhance your understanding of economic ideas beyond that which was presented to you in Principles of Microeconomics. The basic structure of the course is to first study how consumers and firms make choices in the face of scarcity. We will then explore how these choices come together in various market settings.

Textbook(s) and Other Resources

Recommended

- Frank, Robert H. Microeconomics and Behavior. 9th ed. New York: McGraw-Hill, 2021.

Other Resources

- Banerjee, Sourish. Intermediate Microeconomics: A Tool-Building Approach. Routledge, 2014.
- Practice materials posted on Canvas
- Econ Graphs's Website

Learning Objectives

By the end of this course, students should be able to:

- Understand the theoretical foundations of individual choice
- Develop demand curves from individual preference relations
- Build firm and market supply from production theory and costs
- Analyze various market models and their externalities
- Apply the basic tools of game theory to explain strategic decision-making

Grading

Final grades will be based on two exams (a midterm and a final) and quizzes administered through Canvas.

Grading Breakdown

Assignment	Percent of Total Grade	Date
Midterm	26	5/29/2026
Final	26	6/18/2026
Quizzes	48	Bi-weekly

Grading Scale

Letter grade	Percent
A	92.50 - 100
A-	89.50 - 92.49
B+	86.50 - 89.49
B	82.50 - 86.49
B-	79.50 - 82.49
C+	76.50 - 79.49
C	72.50 - 76.49
C-	69.50 - 72.49
D+	66.50 - 69.49
D	62.50 - 66.49
D-	59.50 - 62.49
F	0 - 59.49

Exams

There will be two exams in this course, namely a midterm and (cumulative) final. Each exam is worth 26% of the final grade and will take place during regular class time. Exams are based on content covered both in readings and lectures.

Exam Policies

- No use of electronic devices is allowed during exams. If a student uses any device (cell phone, smart watch, headphones, etc.) during an exam, they will automatically receive a zero on that exam.
- The use of any calculator not provided by the instructor is not allowed. The instructor will provide calculators for all students to use on exam days.
- All exams will take place in our regular classroom and at regular class times. Each will be closed book with no notes allowed.
- No student is allowed to begin their exam once a single student has finished and handed their exam in for submission.

Makeup Exam Policy

Makeup exams will only be permitted if you provide an official excuse from Case Management Services, which addresses prolonged illnesses, deaths of friends or family members, or other significant circumstances. If approved, makeup exams must be scheduled directly with me and completed within one week of the midterm.

Should you miss the midterm, have an official excuse from Case Management, and are unable to complete a makeup exam, the midterm's weight will automatically transfer to the final exam, increasing its weight to 52% of your overall course grade. Students who miss the midterm or final without an official excuse from Case Management (and didn't notify the instructor about missing the midterm during the first week of class) will earn a zero on said exam.

As for the final exam, according to FSU policy, the following are the only valid reasons for requesting a makeup: (1) Three or more final exams within a 24-hour period around our exam; (2) Another exam scheduled at the same time as our exam; (3) A documented medical emergency; (4) Some other documented extraordinary event. If one of these applies to you, you must see me as soon as possible to schedule another time to take the exam. **However, clear and prompt communication is crucial. Should unexpected or emergency situations arise, contacting me immediately will enable us to identify suitable solutions.**

Quizzes

This course will have (roughly) semi-weekly quizzes beginning in the second week of the semester. These quizzes will be administered through Canvas, and will be posted at least two days before the due date and are due by 11:59pm of the date shown on the schedule. Students are allowed three attempts on quizzes, of which only their highest score will count. Quizzes will primarily cover recent material, though they may include any content discussed in lectures or the textbook up to that point.

Quizzes will not be eligible for makeup unless documented evidence confirms you were physically unable to complete them for the entire period they were available. Situations such as becoming ill or encountering extraordinary events within 24 hours of an assignment's due date will not qualify for makeup consideration if sufficient time (e.g., several days) was available earlier in the submission period. Additionally, technical issues, such as internet outages or malfunctioning devices, are not valid reasons for requesting or receiving a makeup.

Extra Credit

In an effort to be equal to all students, no extra credit will be given under any circumstances nor will grades be rounded beyond the 0.5 threshold specified in the grading scale. For example, a score of 89.49 will earn a B+ whereas a 89.50 will earn an A-.

Schedule

Below is a rough outline of the order in which we will cover topics.

Outline of Semester Schedule		
Date	Content Covered	Quiz or Test (if applicable)
May 11	Syllabus + Principles Review	
May 12	Math Review + Bundles	
May 13	Bundles + Budgets	
May 14	Preferences	
May 15	No Class	Quiz 1 Due
May 18	Preferences	
May 19	Consumer Choice	
May 20	Consumer Choice	Quiz 2 Due
May 21	Consumer Choice	
May 22	Aggregate Demand	Quiz 3 Due
May 25	No Class	
May 26	Elasticity	
May 27	Short Run Production	Quiz 4 Due
May 28	Short Run Production	
May 29	None	Midterm
June 1	Short Run Supply	
June 2	Long Run Production	
June 3	Long Run Supply	Quiz 5 Due
June 4	Perfect Competition	
June 5	Externalities	Quiz 6 Due
June 8	Monopolies	
June 9	Price Discrimination	
June 10	Oligopolies	Quiz 7 Due
June 11	Game Theory	
June 12	Game Theory	Quiz 8 Due
June 15	Game Theory	
June 16	Labor + Leisure	
June 17	Labor + Leisure	
June 18	None	Final
June 19	No Class	

University Policies

University Attendance Policy

Excused absences include documented illness, deaths in the family, and other documented crises, call to active military duty or jury duty, religious holy days, and official University activities. These absences will be accommodated in a way that does not arbitrarily penalize students who have a valid written excuse. Consideration will also be given to students whose dependent children experience serious illness.

Academic Honor Policy

The Florida State University Academic Honor Policy outlines the University's expectations for the integrity of student's academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process. Students are responsible for reading the Academic Honor Policy and for living up to their pledge to ". . . be honest and truthful and . . . [to] strive for personal and institutional integrity at Florida State University." (Florida State University Academic Honor Policy, found at <http://fda.fsu.edu/academic-resources/academic-integrity-and-grievances/academic-honor-policy>)

Americans With Disabilities Act

FSU is committed to providing reasonable accommodation for all persons with disabilities in a manner that is consistent with the academic standards of the course while empowering the student to meet the integral requirements of the course. Students with disabilities needing academic accommodation should: (1) register with and provide documentation to the Office of Accessibility Services; and (2) request a letter from the Office of Accessibility Services to be sent to the instructor indicating the need for accommodation and what type; and (3) meet (in person, via phone, email, zoom, etc...) with each instructor to whom a letter of accommodation was sent to review approved accommodations. Please note that instructors are not allowed to provide classroom accommodations to a student until appropriate verification from the Office of Accessibility Services has been provided. This syllabus and other class materials are available in an alternative format upon request. For the latest version of this statement and more information about services available to FSU students with disabilities, contact the:

Office of Accessibility Services
874 Traditions Way
108 Student Services Building
Florida State University
Tallahassee, FL 32306-4167
(850) 644-9566 (voice)
(850) 644-8504 (TDD)
oas@fsu.edu
<https://dsst.fsu.edu/oas>

Academic Success

Your academic success is a top priority for Florida State University. University resources to help you succeed include tutoring centers, computer labs, counseling and health services, and services for designated groups, such as veterans and students with disabilities. The following information is not exhaustive, so please check with your advisor or the Department of Student Support and Transitions to learn more.

Confidential Campus Resources

Various centers and programs are available to assist students with navigating stressors that might impact academic success. These include the following:

Victim Advocate Program
University Center A, Rm. 4100
(850) 644-7161
Available 24/7/365
Office Hours: M-F 8-5
<https://dsst.fsu.edu/vap>

Counseling and Psychological Services (CAPS)

Florida State University's Counseling and Psychological Services (CAPS) primary mission is to address psychological needs and personal concerns, which may interfere with students' academic progress, social development, and emotional well-being. The following in-person and virtual (tele-mental health) services are available to all enrolled students residing in the state of Florida:

1. Individual therapy
2. Group therapy
3. Crisis Intervention
4. Psychoeducational and outreach programming
5. After hours crisis-hotline
6. Access to community providers for specialized treatment

Call 850-644-TALK (8255) for more information on how to initiate services.

Counseling and Psychological Services
250 Askew Student Life Center
942 Learning Way
(850) 644-TALK (8255)
Walk-in and Appointment Hours:
M-F 8 am – 4 pm
<https://counseling.fsu.edu/>

Services at UHS are available to all enrolled students residing in Florida

The mission of University Health Services (UHS) is to promote and improve the overall health and well-being of FSU students. UHS provides a coordinated continuum of care through prevention, intervention, and treatment. Services include general medical care, priority care, gynecological services, physicals, allergy injection clinic, immunizations, diagnostic imaging, physical therapy, and a medical response unit. The Center for Health Advocacy and Wellness (CHAW) assists students in their academic success through individual, group, and population-based health and wellness initiatives. Topics include wellness, alcohol and other drugs, hazing prevention, nutrition and body image, sexual health, and power based personal violence prevention. For more information, go to uhs.fsu.edu.

University Health Services
Health and Wellness Center
960 Learning Way
Tallahassee, FL 32306
Hours: M-F, 8 am – 4 pm
(850) 644-6230
<https://uhs.fsu.edu/>

Free Tutoring from FSU

On-campus tutoring and writing assistance is available for many courses at Florida State University. For more information, visit the Academic Center for Excellence (ACE) Tutoring Services' comprehensive list of on-campus tutoring options –see <https://ace.fsu.edu/tutoring> or contact tutor@fsu.edu. High-quality tutoring is available by appointment and on a walk-in basis. These services are offered by tutors trained to encourage the highest level of individual academic success while upholding personal academic integrity.

Syllabus Change Policy

Except for changes that substantially affect implementation of the evaluation (grading) statement, this syllabus is a guide for the course and is subject to change with advance notice.

Statement on Public Health Protocols

During any adverse event or condition that threatens our University community, please look for specific information on the FSU Alerts page (<https://alerts.fsu.edu/>) to ascertain particulars to the current situation. Please be patient with one another while we navigate any ongoing challenge. Whatever happens, we are committed to helping you learn the material thoroughly and stay on schedule with your degree program.

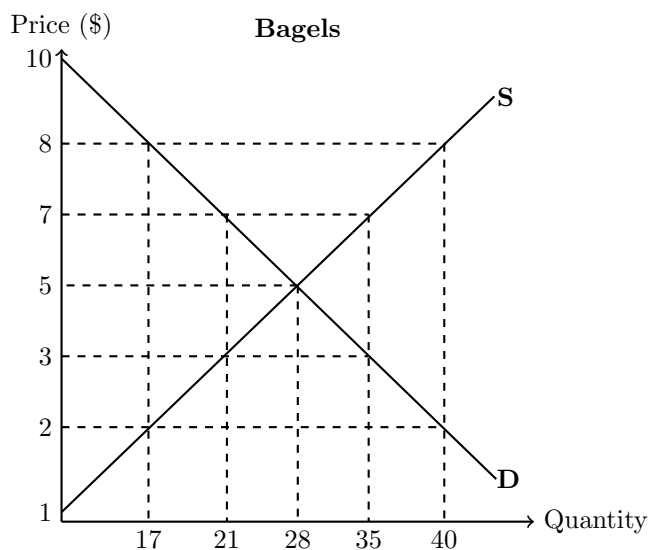
Class Recording Statement

In this class, consistent with state law and university policy, students are permitted to make recordings of class lectures for personal use only. As noted, sharing, posting, or publishing classroom recordings may subject you to honor code violations and legal penalties associated with theft of intellectual property and violations of other state laws. Moreover, students and educators have expressed concern that recording classroom activities may negatively impact the learning experience for others, especially in classes that involve questions, discussion, or participation. To protect a learning environment in which everyone feels free to experiment with ideas, we ask you to refrain from recording in ways that could make others feel reluctant to ask questions, explore new ideas, or otherwise participate in class. Students must monitor their recordings so that they do not include participation by other students without permission. Students with disabilities will continue to have appropriate accommodations for recordings as established by the Office of Accessibility Services.

Practice Problems

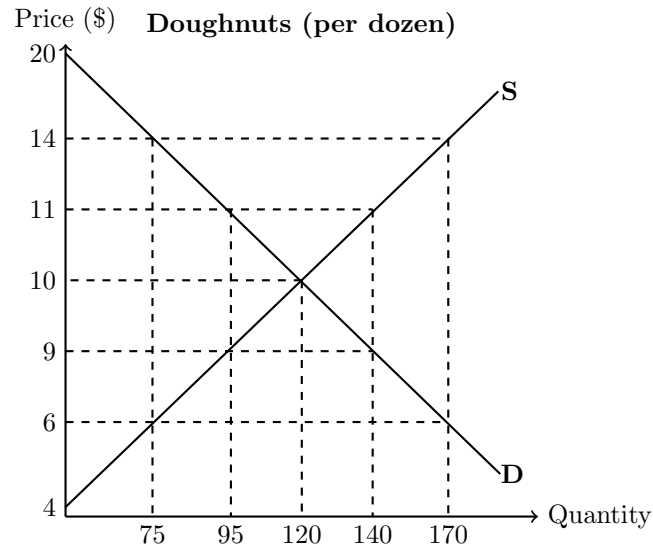
Supply and Demand Review

Use the following graph representing the market of bagels to answer questions 1-12.



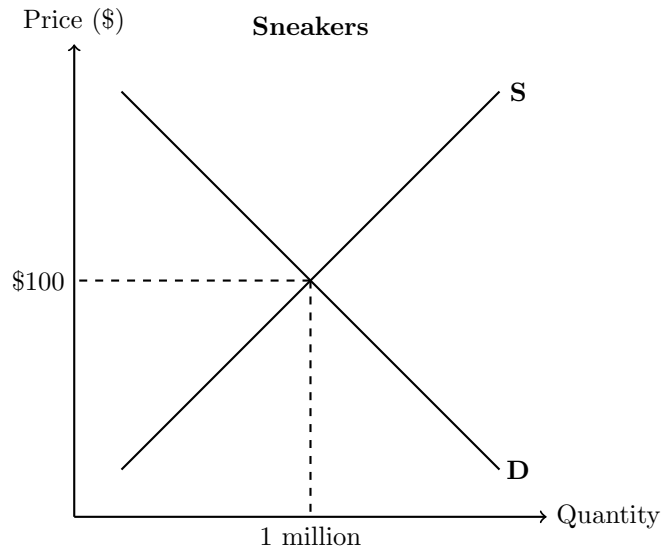
1. What is the equilibrium price(s) in the market for bagels?
2. At what price(s) would this market operate in a surplus?
3. At what price(s) would this market operate in a shortage?
4. The market price for bagels is \$8. Solve for consumer surplus, producer surplus, and dead weight loss.
5. The market price for bagels is \$7. Solve for consumer surplus, producer surplus, and dead weight loss.
6. The market price for bagels is \$5. Solve for consumer surplus, producer surplus, and dead weight loss.
7. The market price for bagels is \$3. Solve for consumer surplus, producer surplus, and dead weight loss.
8. The market price for bagels is \$2. Solve for consumer surplus, producer surplus, and dead weight loss.
9. Suppose this market operates at a price of \$8. Are consumers better or worse off than they would be at equilibrium (and by how much)? What about producers?
10. Suppose this market operates at a price of \$7. Are consumers better or worse off than they would be at equilibrium (and by how much)? What about producers?
11. Suppose this market operates at a price of \$3. Are consumers better or worse off than they would be at equilibrium (and by how much)? What about producers?
12. Suppose this market operates at a price of \$2. Are consumers better or worse off than they would be at equilibrium (and by how much)? What about producers?

Use the following graph representing the market of doughnuts to answer questions 13-24.



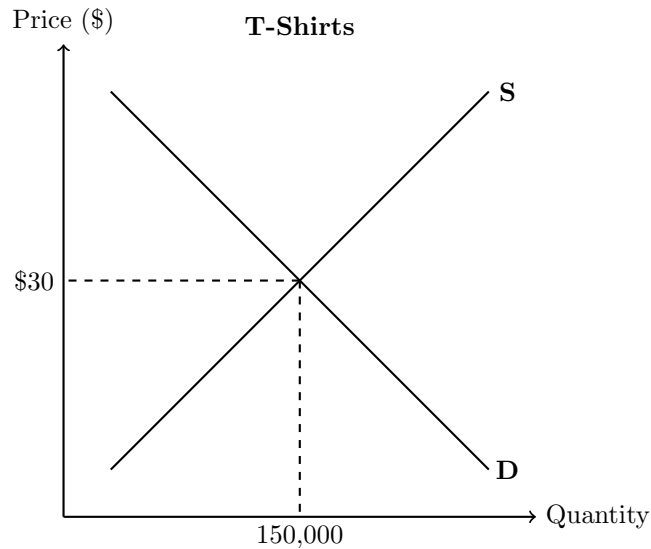
13. What is the equilibrium price(s) in the market for doughnuts?
14. At what price(s) would this market operate in a surplus?
15. At what price(s) would this market operate in a shortage?
16. The market price for doughnuts is \$14. Solve for consumer surplus, producer surplus, and dead weight loss.
17. The market price for doughnuts is \$11. Solve for consumer surplus, producer surplus, and dead weight loss.
18. The market price for doughnuts is \$10. Solve for consumer surplus, producer surplus, and dead weight loss.
19. The market price for doughnuts is \$9. Solve for consumer surplus, producer surplus, and dead weight loss.
20. The market price for doughnuts is \$6. Solve for consumer surplus, producer surplus, and dead weight loss.
21. Suppose this market operates at a price of \$14. Are consumers better or worse off than they would be at equilibrium (and by how much)? What about producers?
22. Suppose this market operates at a price of \$11. Are consumers better or worse off than they would be at equilibrium (and by how much)? What about producers?
23. Suppose this market operates at a price of \$9. Are consumers better or worse off than they would be at equilibrium (and by how much)? What about producers?
24. Suppose this market operates at a price of \$6. Are consumers better or worse off than they would be at equilibrium (and by how much)? What about producers?

Use the following graph representing the market of sneakers to answer questions 25-34. Consider each question by itself (i.e. none of the changes made in previous questions apply, so the market always begins in equilibrium).



25. The market for shoes begins in equilibrium. Suppose the price of shoe laces (that come with the shoe) suddenly quadruples. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
26. The market for shoes begins in equilibrium. Suppose people begin to wear flip flops more often. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
27. The market for shoes begins in equilibrium. Suppose many clothing brands, who previously didn't produce shoes, now begin to make shoes. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
28. The market for shoes begins in equilibrium. Suppose everyone's income suddenly doubles and sneakers are a normal good. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
29. The market for shoes begins in equilibrium. Suppose the price of socks increases. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
30. The market for shoes begins in equilibrium. Suppose there is a sudden baby boom across the globe. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
31. The market for shoes begins in equilibrium. Suppose heels become less expensive. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
32. The market for shoes begins in equilibrium. Suppose people now expect sneaker prices to decrease in the future. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
33. The market for shoes begins in equilibrium. Suppose the price of rubber decreases at the same time that people begin going barefoot often. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
34. The market for shoes begins in equilibrium. Suppose everyone gets a stimulus check from the government at the same time that a new (and better) sneaker making robot comes out. Sneakers are a normal good. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?

Use the following graph representing the market of t-shirts to answer questions 35-44. Consider each question by itself (i.e. none of the changes made in previous questions apply, so the market always begins in equilibrium).



35. The market for t-shirts begins in equilibrium. Suppose people begin to wear button shirts instead of t-shirts. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
36. The market for t-shirts begins in equilibrium. Suppose many tech companies now expand to produce t-shirts. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
37. The market for t-shirts begins in equilibrium. Suppose the price of shorts decreases. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
38. The market for t-shirts begins in equilibrium. Suppose t-shirts become the new business attire. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
39. The market for t-shirts begins in equilibrium. Suppose a new t-shirt making process comes out which is better than the old technology. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
40. The market for t-shirts begins in equilibrium. Suppose all government workers get a pay raise and t-shirts are an inferior good. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
41. The market for t-shirts begins in equilibrium. Suppose the price of long sleeve shirts increases. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
42. The market for t-shirts begins in equilibrium. Suppose everyone expects the price of t-shirts to increase in a few months. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
43. The market for t-shirts begins in equilibrium. Suppose the price of cotton decreases and global warming intensifies. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?
44. The market for t-shirts begins in equilibrium. Suppose the price of sewing string increases and people have a new disdain for people who wear t-shirts. What happens to supply, demand, quantity supplied, quantity demanded, market quantity, and market price?

45. Consider the market for coffee. Suppose there becomes a growing coffee culture and there is a coffee-eating bug infestation in Latin America. What happens to supply, demand, market quantity, and market price?
46. Consider the market for compact cars. Suppose people begin having larger families and the cost of rubber decreases. What happens to supply, demand, market quantity, and market price?
47. Consider the market for wheat. Suppose a new diet trend starts which promotes low-carbs and gluten-free food. At the same time, the cost of gasoline increases. What happens to supply, demand, market quantity, and market price?
48. Consider the market for electric vehicles. Suppose people become more conscious of global warming and battery production improves. What happens to supply, demand, market quantity, and market price?
49. Consider the market for flights in the Bahamas. Suppose summer begins and a new larger plane is introduced. What happens to supply, demand, market quantity, and market price?
50. Consider the market for gasoline powered cars. Suppose the price of electric cars decreases. What happens to supply, demand, market quantity, and market price?
51. Consider the market for streaming services. Suppose a new season of a hit TV show comes out on Netflix (e.g. Stranger Things) and the actors union reduces the minimum price paid to actors. What happens to supply, demand, market quantity, and market price?
52. Consider the market for landline phones (home phones connected to the wall via wire). Suppose the iPhone is introduced making the landline obsolete and the cost of the wire connected to the phone increases. What happens to supply, demand, market quantity, and market price?
53. Consider the market for online grocery delivery (GrubHub, InstaCart, DoorDash, etc.). Suppose people begin to prioritize convenience more than they did previously and more companies enter the market. What happens to supply, demand, market quantity, and market price?
54. Consider the market for diamonds. Suppose many people plan to propose this year and many labs which produce diamonds burn down. What happens to supply, demand, market quantity, and market price?
55. Consider the market for computers. Suppose everyone believes the price of computers will go up in the future. What happens to supply, demand, market quantity, and market price?
56. Consider the market for computers. Suppose only consumers believe the price of computers will go up in the future. What happens to supply, demand, market quantity, and market price? (Notice the difference in the wording from question 55).

Answers

1. \$5
2. \$7 and \$8
3. \$2 and \$3
4. $CS = \frac{1}{2} \times \$2 \times 17 = \$17$
 $PS = \frac{1}{2} \times (\$7 + \$6) \times 17 = \110.50
 $DWL = \frac{1}{2} \times \$6 \times 11 = \$33$
5. $CS = \frac{1}{2} \times \$3 \times 21 = \$31.50$
 $PS = \frac{1}{2} \times (\$6 + \$4) \times 21 = \105
 $DWL = \frac{1}{2} \times \$4 \times 7 = \$14$
6. $CS = \frac{1}{2} \times \$5 \times 28 = \$70$
 $PS = \frac{1}{2} \times \$4 \times 28 = \$56$
 $DWL = \$0$
7. $CS = \frac{1}{2} \times (\$7 + \$4) \times 21 = \115.50
 $PS = \frac{1}{2} \times \$2 \times 21 = \$21$
 $DWL = \frac{1}{2} \times \$4 \times 7 = \$14$
8. $CS = \frac{1}{2} \times (\$8 + \$6) \times 17 = \119
 $PS = \frac{1}{2} \times \$1 \times 17 = \$8.60$
 $DWL = \frac{1}{2} \times \$6 \times 11 = \$33$
9. Consumers are \$53 (\$70-\$17) worse off. Producers are \$54.50 (\$110.50 - \$56) better off.
10. Consumers are \$38.50 (\$70-\$31.50) worse off. Producers are \$49 (\$105 - \$56) better off.
11. Consumers are \$45.50 (\$115.50-\$70) better off. Producers are \$35 (\$56 - \$21) worse off.
12. Consumers are \$49 (\$119-\$70) better off. Producers are \$47.50 (\$56 - \$8.50) worse off.
13. \$10
14. \$11 and \$14
15. \$6 and \$9
16. $CS = \frac{1}{2} \times \$(20 - 14) \times 75 = \$225$
 $PS = \frac{1}{2} \times \$(10 + 8) \times 75 = \$675$
 $DWL = \frac{1}{2} \times \$8 \times 45 = \$180$
17. $CS = \frac{1}{2} \times \$(20 - 11) \times 95 = \$427.50$
 $PS = \frac{1}{2} \times \$(7 + 2) \times 95 = \$427.50$
 $DWL = \frac{1}{2} \times \$2 \times 95 = \$95$
18. $CS = \frac{1}{2} \times \$(20 - 10) \times 120 = \$600$
 $PS = \frac{1}{2} \times \$(10 - 4) \times 120 = \$360$
 $DWL = \$0$
19. $CS = \frac{1}{2} \times \$(11 + 2) \times 95 = \$617.50$
 $PS = \frac{1}{2} \times \$ \times 95 = \237.50
 $DWL = \frac{1}{2} \times \$2 \times 95 = \$95$
20. $CS = \frac{1}{2} \times \$6 \times 75 = \$825$
 $PS = \frac{1}{2} \times \$(6 - 4) \times 75 = \$75$
 $DWL = \frac{1}{2} \times \$8 \times 45 = \$180$

21. Consumers are \$375 worse off ($\$600 - \225). Producers are \$315 better off ($\$675 - \360).
22. Consumers are \$172.50 worse off ($\$600 - \427.50). Producers are \$67.50 better off ($\$427.50 - \360).
23. Consumers are \$17.50 better off ($\$617.50 - \600). Producers are \$122.50 worse off ($\$360 - \237.50).
24. Consumers are \$225 better off ($\$825 - \600). Producers are \$285 worse off ($\$360 - \75).
25. Supply: Decreases
Demand: No change
Quantity supplied: Decreases
Quantity demanded: Decreases
Market quantity: Decreases
Market price: Increases
26. Supply: No change
Demand: Decreases
Quantity supplied: Increases
Quantity demanded: Increases
Market quantity: Increases
Market price: Increases
27. Supply: Increases
Demand: No change
Quantity supplied: Increases
Quantity demanded: Increases
Market quantity: Increases
Market price: Decreases
28. Supply: No change
Demand: Increases
Quantity supplied: Increases
Quantity demanded: Increases
Market quantity: Increases
Market price: Increases
29. Supply: No change
Demand: Decreases
Quantity supplied: Decreases
Quantity demanded: Decreases
Market quantity: Decreases
Market price: Decreases
30. Supply: No change
Demand: Increases
Quantity supplied: Increases
Quantity demanded: Increases
Market quantity: Increases
Market price: Increases
31. Supply: Increases
Demand: Decreases
Quantity supplied: Ambiguous
Quantity demanded: Ambiguous
Market quantity: Ambiguous
Market price: Decreases

32. Supply: Decreases
Demand: Increases
Quantity supplied: Ambiguous
Quantity demanded: Ambiguous
Market quantity: Ambiguous
Market price: Increases
33. Supply: Increases
Demand: Decreases
Quantity supplied: Ambiguous
Quantity demanded: Ambiguous
Market quantity: Ambiguous
Market price: Decreases
34. Supply: Increases
Demand: Increases
Quantity supplied: Increases
Quantity demanded: Increases
Market quantity: Increases
Market price: Ambiguous
35. Supply: No change
Demand: Decreases
Quantity supplied: Decreases
Quantity demanded: Decreases
Market quantity: Decreases
Market price: Decreases
36. Supply: Increases
Demand: No change
Quantity supplied: Increases
Quantity demanded: Increases
Market quantity: Increases
Market price: Decreases
37. Supply: No change
Demand: Increases
Quantity supplied: Increases
Quantity demanded: Increases
Market quantity: Increases
Market price: Increases
38. Supply: No change
Demand: Increases
Quantity supplied: Increases
Quantity demanded: Increases
Market quantity: Increases
Market price: Increases

39. Supply: Increases
Demand: No change
Quantity supplied: Increases
Quantity demanded: Increases
Market quantity: Increases
Market price: Decreases
40. Supply: No change
Demand: Decreases
Quantity supplied: Decreases
Quantity demanded: Decreases
Market quantity: Decreases
Market price: Decreases
41. Supply: Decreases
Demand: Increases
Quantity supplied: Ambiguous
Quantity demanded: Ambiguous
Market quantity: Ambiguous
Market price: Increases
42. Supply: Decreases
Demand: Increases
Quantity supplied: Ambiguous
Quantity demanded: Ambiguous
Market quantity: Ambiguous
Market price: Increases
43. Supply: Increases
Demand: Increases
Quantity supplied: Increases
Quantity demanded: Increases
Market quantity: Increases
Market price: Ambiguous
44. Supply: Decreases
Demand: Decreases
Quantity supplied: Decreases
Quantity demanded: Decreases
Market quantity: Decreases
Market price: Ambiguous
45. Supply: Decreases
Demand: Increases
Market quantity: The effect is ambiguous.
Market price: Increases
46. Supply: Increases
Demand: Increases
Market quantity: Increases
Market price: The effect is ambiguous

47. Supply: Decreases
Demand: Decreases
Market quantity: Decreases
Market price: The effect is ambiguous.
48. Supply: Increases
Demand: Decreases
Market quantity: The effect is ambiguous.
Market price: Decreases
49. Supply: Increases
Demand: Increases
Market quantity: Increases
Market price: The effect is ambiguous.
50. Supply: Increases
Demand: Decreases
Market quantity: The effect is ambiguous.
Market price: Decreases
51. Supply: Increases
Demand: Increases
Market quantity: Increases
Market price: The effect is ambiguous.
52. Supply: Decreases
Demand: Decreases
Market quantity: Decreases
Market price: The effect is ambiguous.
53. Supply: Increases
Demand: Increases
Market quantity: Increases
Market price: The effect is ambiguous.
54. Supply: Decreases
Demand: Increases
Market quantity: The effect is ambiguous.
Market price: Increases
55. Supply: Decreases
Demand: Increases
Market quantity: The effect is ambiguous.
Market price: Increases
56. Supply: No change
Demand: Increases
Market quantity: Increases
Market price: Increases

Math Review

Calculate the derivative of each of the following functions.

1. $y = 23x$
2. $y = 9x + 10$
3. $y = 15x - 4x$
4. $y = 10x^2$
5. $y = 3x^2 + 5$
6. $\sqrt{x}$
7. $\frac{1}{2}x^{-2}$
8. $y = 6x + 3x^2$
9. $y = \frac{1}{10}x^4 - 2x^2 + 5$
10. $y = \frac{1}{5}x^{-3} + x^{\frac{1}{10}} + 4$
11. $f(x) = \frac{1}{5}x$
12. $f(x) = 100x - 9$
13. $f(x) = 20x^{\frac{1}{3}}$
14. $f(x) = 3x^8$
15. $f(x) = 4x^2 + 3\sqrt{x}$
16. $f(x) = 2x^{\frac{1}{3}} - 5x + 15$
17. $f(x) = 4x^2 - x - 4$
18. $f(x) = -3x^{-2} + \frac{1}{5}x$
19. $f(x) = 3\sqrt{x} - 4x + 5$
20. $f(x) = 4x^{-3} - 2x^2 + 8x - 7$
21. $P = 6Q$
22. $P = 1,000Q + 15,000$
23. $P = 10Q^3 - 40$
24. $P = 400\sqrt{Q}$
25. $P = 5,000Q^2$
26. $P = 6Q^{\frac{1}{4}} - 10Q + 40$
27. $P = 4Q^3 - Q^{-2}$
28. $P = 4Q - \frac{1}{Q} + 4$
29. $P = 10Q^{-4} + \frac{1}{4}Q$
30. $P = 1,500Q^{-3} - 40Q^{\frac{1}{3}} + 10$
31. $f(x, y) = 3x - 2y$
32. $f(x, y) = -5x + 10y - 3$
33. $f(x, y) = 4x^2 - 10y - 2$
34. $f(x, y) = 4x^2 + x - 3y^2 + 7y - 4$
35. $f(x, y) = 2x^4 + 3\sqrt{x} - 8x - 2x^{-\frac{1}{2}}$
36. $f(x, y) = 5x - 3y^5 - 2y^3 + y$
37. $f(x, y) = 3y^2 - 10$
38. $f(x, y) = 10x^{12} - \sqrt{x} - 8$
39. $f(x, y) = 4 - 2x^4 + 2x^{\frac{1}{3}} - 10y$
40. $f(x, y) = 10 - 3x^{\frac{1}{2}} - 2x + 4y^9 + 6x^5$

Calculate the derivative of each of the following functions at the point given.

41. $y = 10$ at $x = 5$
42. $y = x^{\frac{1}{3}}$ at $x = 10$
43. $y = \frac{1}{4}x^2 + 20$ at $x = 3$
44. $y = 3x^4 - 5x^2$ at $x = 2$
45. $y = 32x^2 + x^{\frac{1}{5}} + 2$ at $x = 4$
46. $f(x) = 3x$ at $x = 0$
47. $f(x) = 42x^3$ at $x = 2$
48. $f(x) = 10x - 3x$ at $x = 15$
49. $f(x) = \sqrt{x} - x$ at $x = 5$
50. $f(x) = 3x^2 - 4x + 5$ at $x = 10$
51. $P = 4Q - 10$ at $Q = 20$
52. $P = 2Q^5$ at $Q = 2$
53. $P = 10Q^4 - 2Q$ at $Q = 7$
54. $P = -12Q^{-4}$ at $Q = 3$
55. $P = 3Q^2 - 2Q + 4$ at $Q = 5$

Answers

1. $y = 23x \Rightarrow \frac{dy}{dx} = 23$
2. $y = 9x + 10 \Rightarrow \frac{dy}{dx} = 9$
3. $y = 15x - 4x = 11x \Rightarrow \frac{dy}{dx} = 11$
4. $y = 10x^2 \Rightarrow \frac{dy}{dx} = 2 \cdot 10x^{2-1} = 20x$
5. $y = 3x^2 + 5 \Rightarrow \frac{dy}{dx} = 2 \cdot 3x^{2-1} + 0 = 6x$
6. $y = \sqrt{x} = x^{\frac{1}{2}} \Rightarrow \frac{dy}{dx} = \frac{1}{2}x^{\frac{1}{2}-1} = \frac{1}{2}x^{-\frac{1}{2}}$
7. $y = \frac{1}{2}x^{-2} \Rightarrow \frac{dy}{dx} = -2 \cdot \frac{1}{2}x^{-2-1} = -x^{-3}$
8. $y = 6x + 3x^2 \Rightarrow \frac{dy}{dx} = 6 + 2 \cdot 3x^{2-1} = 6 + 6x$
9. $y = \frac{1}{10}x^4 - 2x^2 + 5 \Rightarrow \frac{dy}{dx} = 4 \cdot \frac{1}{10}x^{4-1} - 2 \cdot 2x^{2-1} + 0 = \frac{2}{5}x^3 - 4x$
10. $y = \frac{1}{5}x^{-3} + x^{\frac{1}{10}} + 4 \Rightarrow \frac{dy}{dx} = -3 \cdot \frac{1}{5}x^{-3-1} + \frac{1}{10}x^{\frac{1}{10}-1} + 0 = -\frac{3}{5}x^{-4} + \frac{1}{10}x^{-\frac{9}{10}}$
11. $f(x) = \frac{1}{5}x \Rightarrow f'(x) = \frac{1}{5}$
12. $f(x) = 100x - 9 \Rightarrow f'(x) = 100$
13. $f(x) = 20x^{\frac{1}{3}} \Rightarrow f'(x) = \frac{1}{3} \cdot 20x^{\frac{1}{3}-1} = \frac{20}{3}x^{-\frac{2}{3}}$
14. $f(x) = 3x^8 \Rightarrow f'(x) = 8 \cdot 3x^{8-1} = 24x^7$
15. $f(x) = 4x^2 + 3\sqrt{x} = 4x^2 + 3x^{\frac{1}{2}} \Rightarrow f'(x) = 2 \cdot 4x^{2-1} + \frac{1}{2} \cdot 3x^{\frac{1}{2}-1} = 8x + \frac{3}{2}x^{-\frac{1}{2}}$
16. $f(x) = 2x^{\frac{1}{3}} - 5x + 15 \Rightarrow f'(x) = \frac{1}{3} \cdot 2x^{\frac{1}{3}-1} - 5 + 0 = \frac{2}{3}x^{-\frac{2}{3}} - 5$
17. $f(x) = 4x^2 - x - 4 \Rightarrow f'(x) = 2 \cdot 4x^{2-1} - 1 - 0 = 8x - 1$
18. $f(x) = -3x^{-2} + \frac{1}{5}x \Rightarrow f'(x) = -2 \cdot (-3)x^{-2-1} + \frac{1}{5} = 6x^{-3} + \frac{1}{5}$
19. $f(x) = 3\sqrt{x} - 4x + 5 = 3x^{\frac{1}{2}} - 4x + 5 \Rightarrow f'(x) = \frac{1}{2} \cdot 3x^{-\frac{1}{2}} - 4 = \frac{3}{2}x^{-\frac{1}{2}} - 4$
20. $f(x) = 4x^{-3} - 2x^2 + 8x - 7 \Rightarrow f'(x) = -3 \cdot 4x^{-3-1} - 2 \cdot 2x^{2-1} + 8 - 0 = -12x^{-4} - 4x + 8$
21. $P = 6Q \Rightarrow \frac{dP}{dQ} = 6$
22. $P = 1,000Q + 15,000 \Rightarrow \frac{dP}{dQ} = 1,000$
23. $P = 10Q^3 - 40 \Rightarrow \frac{dP}{dQ} = 3 \cdot 10Q^{3-1} - 0 = 30Q^2$
24. $P = 400\sqrt{Q} = 400Q^{\frac{1}{2}} \Rightarrow \frac{dP}{dQ} = \frac{1}{2} \cdot 400Q^{\frac{1}{2}-1} = 200Q^{-\frac{1}{2}}$
25. $P = 5,000Q^2 \Rightarrow \frac{dP}{dQ} = 2 \cdot 5,000Q^{2-1} = 10,000Q$
26. $P = 6Q^{\frac{1}{4}} - 10Q + 40 \Rightarrow \frac{dP}{dQ} = \frac{1}{4} \cdot 6Q^{\frac{1}{4}-1} - 10 + 0 = \frac{3}{2}Q^{-\frac{3}{4}} - 10$
27. $P = 4Q^3 - Q^{-2} \Rightarrow \frac{dP}{dQ} = 3 \cdot 4Q^{3-1} - (-2)Q^{-2-1} = 12Q^2 + 2Q^{-3}$
28. $P = 4Q - \frac{1}{Q} + 4 = 4Q - Q^{-1} + 4 \Rightarrow \frac{dP}{dQ} = 4 - (-1)Q^{-1-1} + 0 = 4 + Q^{-2}$
29. $P = 10Q^{-4} + \frac{1}{4}Q \Rightarrow \frac{dP}{dQ} = -4 \cdot 10Q^{-4-1} + \frac{1}{4} = -40Q^{-5} + \frac{1}{4}$
30. $P = 1,500Q^{-3} - 40Q^{\frac{1}{3}} + 10 \Rightarrow \frac{dP}{dQ} = -3 \cdot 1,500Q^{-3-1} - \frac{1}{3} \cdot 40Q^{\frac{1}{3}-1} + 0 = -4,500Q^{-4} - \frac{40}{3}Q^{-\frac{2}{3}}$
31. $\frac{\partial f}{\partial x} = 3$ and $\frac{\partial f}{\partial y} = -2$
32. $\frac{\partial f}{\partial x} = -5$ and $\frac{\partial f}{\partial y} = 10$
33. $\frac{\partial f}{\partial x} = 2 \cdot 4x^{2-1} = 8x$ and $\frac{\partial f}{\partial y} = -10$

34. $\frac{\partial f}{\partial x} = 2 \cdot 4x^{2-1} + 1 = 8x + 1$ and $\frac{\partial f}{\partial y} = -2 \cdot 3y^{2-1} + 7 = -6y + 7$
35. $\frac{\partial f}{\partial x} = 4 \cdot 2x^{4-1} + \frac{1}{2} \cdot 3x^{\frac{1}{2}-1} - 8 + \frac{1}{2} \cdot 2x^{-\frac{1}{2}-1} = 8x^3 + \frac{3}{2}x^{-\frac{1}{2}} - 8 + x^{-\frac{3}{2}}$ and $\frac{\partial f}{\partial y} = 0$
36. $\frac{\partial f}{\partial x} = 5$ and $\frac{\partial f}{\partial y} = -5 \cdot 3y^{5-1} - 3 \cdot 2y^{3-1} + 1 = -15y^4 - 6y^2 + 1$
37. $\frac{\partial f}{\partial x} = 0$ and $\frac{\partial f}{\partial y} = 2 \cdot 3y^{2-1} = 6y$
38. $\frac{\partial f}{\partial x} = 12 \cdot 10x^{12-1} - \frac{1}{2}x^{\frac{1}{2}-1} = 120x^{11} - \frac{1}{2}x^{-\frac{1}{2}}$ and $\frac{\partial f}{\partial y} = 0$
39. $\frac{\partial f}{\partial x} = -4 \cdot 2x^{4-1} + \frac{1}{3} \cdot 2x^{\frac{1}{3}-1} = -8x^3 + \frac{2}{3}x^{-\frac{2}{3}}$ and $\frac{\partial f}{\partial y} = -10$
40. $\frac{\partial f}{\partial x} = -\frac{1}{2} \cdot 3x^{\frac{1}{2}-1} - 2 + 5 \cdot 6x^{5-1} = -\frac{3}{2}x^{-\frac{1}{2}} - 2 + 30x^4$ and $\frac{\partial f}{\partial y} = 9 \cdot 4y^{9-1} = 36y^8$
41. $y = 10$ at $x = 5 \Rightarrow \frac{dy}{dx} = 0 \Rightarrow \frac{dy}{dx} = 0$ at $x = 5$
42. $y = x^{\frac{1}{3}}$ at $x = 10 \Rightarrow \frac{dy}{dx} = \frac{1}{3}x^{-\frac{2}{3}} \Rightarrow \frac{dy}{dx} = \frac{1}{3}(10)^{-\frac{2}{3}} = \frac{1}{3 \cdot 10^{\frac{2}{3}}} = \frac{1}{3\sqrt[3]{100}}$ at $x = 10$
43. $y = \frac{1}{4}x^2 + 20$ at $x = 3 \Rightarrow \frac{dy}{dx} = \frac{1}{2}x \Rightarrow \frac{dy}{dx} = \frac{1}{2}(3) = \frac{3}{2}$ at $x = 3$
44. $y = 3x^4 - 5x^2$ at $x = 2 \Rightarrow \frac{dy}{dx} = 12x^3 - 10x \Rightarrow \frac{dy}{dx} = 12(2)^3 - 10(2) = 96 - 20 = 76$ at $x = 2$
45. $y = 32x^2 + x^{\frac{1}{5}} + 2$ at $x = 4 \Rightarrow \frac{dy}{dx} = 64x + \frac{1}{5}x^{-\frac{4}{5}} \Rightarrow \frac{dy}{dx} = 64(4) + \frac{1}{5}(4)^{-\frac{4}{5}} = 256 + \frac{1}{5 \cdot 4^{\frac{4}{5}}} = 256 + \frac{1}{5\sqrt[5]{256}}$ at $x = 4$
46. $f(x) = 3x$ at $x = 0 \Rightarrow f'(x) = 3 \Rightarrow f'(0) = 3$ at $x = 0$
47. $f(x) = 42x^3$ at $x = 2 \Rightarrow f'(x) = 126x^2 \Rightarrow f'(2) = 126(2)^2 = 504$ at $x = 2$
48. $f(x) = 10x - 3x = 7x$ at $x = 15 \Rightarrow f'(x) = 7 \Rightarrow f'(15) = 7$ at $x = 15$
49. $f(x) = x^{\frac{1}{2}} - x$ at $x = 5 \Rightarrow f'(x) = \frac{1}{2}x^{-\frac{1}{2}} - 1 \Rightarrow f'(5) = \frac{1}{2\sqrt{5}} - 1 = \frac{\sqrt{5}}{10} - 1$ at $x = 5$
50. $f(x) = 3x^2 - 4x + 5$ at $x = 10 \Rightarrow f'(x) = 6x - 4 \Rightarrow f'(10) = 6(10) - 4 = 56$ at $x = 10$
51. $P = 4Q - 10$ at $Q = 20 \Rightarrow \frac{dP}{dQ} = 4 \Rightarrow \frac{dP}{dQ} = 4$ at $Q = 20$
52. $P = 2Q^5$ at $Q = 2 \Rightarrow \frac{dP}{dQ} = 10Q^4 \Rightarrow \frac{dP}{dQ} = 10(2)^4 = 160$ at $Q = 2$
53. $P = 10Q^4 - 2Q$ at $Q = 7 \Rightarrow \frac{dP}{dQ} = 40Q^3 - 2 \Rightarrow \frac{dP}{dQ} = 40(7)^3 - 2 = 13,720 - 2 = 13,718$ at $Q = 7$
54. $P = -12Q^{-4}$ at $Q = 3 \Rightarrow \frac{dP}{dQ} = 48Q^{-5} \Rightarrow \frac{dP}{dQ} = \frac{48}{3^5} = \frac{48}{243} = \frac{16}{81}$ at $Q = 3$
55. $P = 3Q^2 - 2Q + 4$ at $Q = 5 \Rightarrow \frac{dP}{dQ} = 6Q - 2 \Rightarrow \frac{dP}{dQ} = 6(5) - 2 = 28$ at $Q = 5$

Budget Sets

Consider FSU has \$100,000 and can buy either laptops for \$2,500 or iPads for \$1,000 to answer questions 1-20.

1. Draw FSU's budget set.
2. What is the most laptops that FSU can buy?
3. What is the most iPads that FSU can buy?
4. Can FSU afford to buy 35 laptops and 12 iPads?
5. Can FSU buy 10 laptops and 30 iPads?
6. Can FSU buy 2 laptops and 98 iPads?
7. Can FSU afford 42 laptops and 15 iPads?
8. FSU decides they must buy 30 iPads. What is the greatest number of laptops they can buy?

For questions 9-13, the price of laptops decreases to \$2,000.

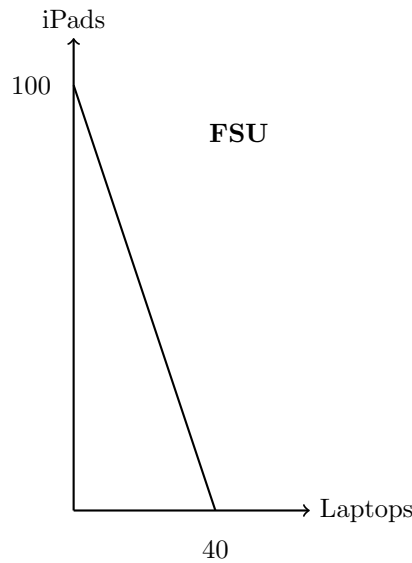
9. Draw FSU's new budget set.
10. Can FSU afford 42 laptops and 15 iPads?
11. Can FSU afford 4 laptops and 90 iPads?
12. Can FSU afford 20 laptops and 50 iPads?
13. What is the greatest number of iPads that FSU can buy if they choose to buy 10 laptops?

Dell now gives FSU a bulk deal on laptops. The first 20 laptops cost \$2,000, but after that they cost \$1,500 per laptop. Use this information to answer questions 14-20.

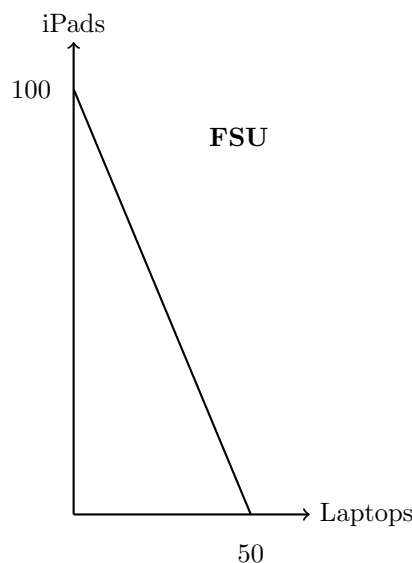
14. Draw FSU's new budget set.
15. What is the most laptops that FSU can buy?
16. What is the most iPads that FSU can buy?
17. Can FSU buy 25 laptops and 60 iPads?
18. Can FSU buy 20 laptops and 40 iPads?
19. FSU needs to buy 30 laptops. What is the maximum number of iPads that FSU can buy?
20. What is the greatest number of iPads that FSU can buy if they choose to buy 60 laptops?

Answers

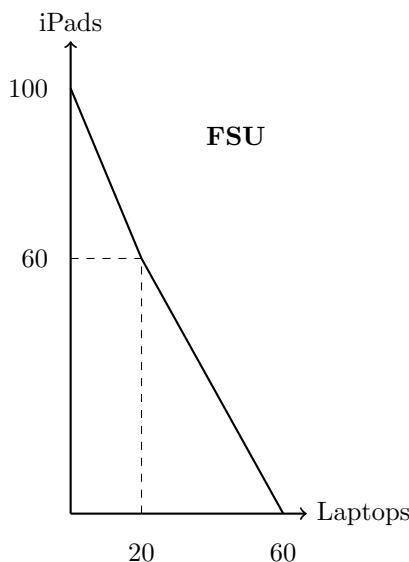
1. The figure below represents the budget set.



2. The most laptops FSU can buy is $\frac{\$100,000}{\$2,500} = 40$ laptops.
3. The most iPads FSU can buy is $\frac{\$100,000}{\$1,000} = 100$ iPads.
4. $35 \times \$2,500 + 12 \times \$1,000 = \$87,500 + \$12,000 = \$99,500 \leq \$100,000$. Yes, FSU can afford a bundle of 35 laptops and 12 iPads.
5. $10 \times \$2,500 + 30 \times \$1,000 = \$25,000 + \$30,000 = \$55,000 \leq \$100,000$. Yes, FSU can buy a bundle of 10 laptops and 30 iPads.
6. $2 \times \$2,500 + 98 \times \$1,000 = \$5,000 + \$98,000 = \$103,000 > \$100,000$. No, FSU cannot buy a bundle of 2 laptops and 98 iPads.
7. $42 \times \$2,500 + 15 \times \$1,000 = \$105,000 + \$15,000 = \$120,000 > \$100,000$. No, FSU cannot afford a bundle of 42 laptops and 15 iPads.
8. FSU buys 30 iPads at \$1,000 each, spending $30 \times \$1,000 = \$30,000$. The remaining budget is $\$100,000 - \$30,000 = \$70,000$. The greatest number of laptops is $\frac{\$70,000}{\$2,500} = 28$ laptops.
9. The figure below represents the budget set.



10. $42 \times \$2,000 + 15 \times \$1,000 = \$84,000 + \$15,000 = \$99,000 \leq \$100,000$. Yes, FSU can afford a bundle of 42 laptops and 15 iPads.
11. $4 \times \$2,000 + 90 \times \$1,000 = \$8,000 + \$90,000 = \$98,000 \leq \$100,000$. Yes, FSU can afford a bundle of 4 laptops and 90 iPads.
12. $20 \times \$2,000 + 50 \times \$1,000 = \$40,000 + \$50,000 = \$90,000 \leq \$100,000$. Yes, FSU can afford a bundle of 20 laptops and 50 iPads.
13. FSU buys 10 laptops at \$2,000 each, spending $10 \times \$2,000 = \$20,000$. The remaining budget is $\$100,000 - \$20,000 = \$80,000$. The greatest number of iPads FSU can buy is $\frac{\$80,000}{\$1,000} = 80$ iPads.
14. The figure below represents the budget set.



15. The most laptops FSU can buy is found by spending the entire budget on laptops. The first 20 laptops cost $20 \times \$2,000 = \$40,000$, leaving $\$100,000 - \$40,000 = \$60,000$. The remaining laptops cost $\frac{\$60,000}{\$1,500} = 40$ additional laptops. The most laptops FSU can buy is $20 + 40 = 60$ laptops.
16. The most iPads FSU can buy is $\frac{\$100,000}{\$1,000} = 100$ iPads.
17. FSU buys 20 laptops at \$2,000 each and 5 more at \$1,500 each, spending $20 \times \$2,000 + 5 \times \$1,500 = \$40,000 + \$7,500 = \$47,500$. The remaining budget is $\$100,000 - \$47,500 = \$52,500$. Since $60 \times \$1,000 = \$60,000 > \$52,500$, No, FSU cannot buy a bundle of 25 laptops and 60 iPads.
18. FSU buys 20 laptops at \$2,000 each, spending $20 \times \$2,000 = \$40,000$. The remaining budget is $\$100,000 - \$40,000 = \$60,000$. Since $40 \times \$1,000 = \$40,000 \leq \$60,000$, Yes, FSU can buy a bundle of 20 laptops and 40 iPads.
19. FSU buys 20 laptops at \$2,000 each and 10 more at \$1,500 each, spending $20 \times \$2,000 + 10 \times \$1,500 = \$40,000 + \$15,000 = \$55,000$. The remaining budget is $\$100,000 - \$55,000 = \$45,000$. The maximum number of iPads is $\frac{\$45,000}{\$1,000} = 45$ iPads.
20. FSU buys 20 laptops at \$2,000 each and 40 more at \$1,500 each, spending $20 \times \$2,000 + 40 \times \$1,500 = \$40,000 + \$60,000 = \$100,000$. The remaining budget is $\$100,000 - \$100,000 = \$0$. The greatest number of iPads FSU can buy is 0 iPads.

Preferences

Chase may purchase either Coke for \$6 per case or Powerade for \$5 per pack. Chases preferences are represented by the following utility function $U(C, P) = 3C^{\frac{1}{6}} + 2P^{\frac{1}{4}}$. Use this information to answer questions 1-13.

1. How much utility does Chase get from a bundle of 10 cases of Coke and 26 packs of Powerade?
2. How much utility does Chase get from a bundle of 25 cases of Coke and 6 packs of Powerade?
3. How much utility does Chase get from a bundle of 15 cases of Coke and 18 packs of Powerade?
4. In what order does Chase prefer the following bundles (10 Cokes, 26 Powerades), (25 Cokes, 6 Powerades), and (15 Cokes, 18 Powerades).
5. Chase may choose either a bundle with 64 Cokes and 625 Powerades or 4,096 Cokes and 16 Powerades. Which bundle should Chase choose? What can we say about the relationship between these two bundles?
6. Are Chase's preferences complete?
7. Are Chase's preferences transitive?
8. Is Chase rational?
9. What is Chase's marginal utility of Coke?
10. What is Chase's marginal utility of Powerade?
11. Does Chase exhibit diminishing marginal utility in Coke?
12. Does Chase exhibit diminishing marginal utility in Powerade?
13. What is Chase's marginal rate of substitution between Coke and Powerade?

Joan needs to purchase t-shirts and pants for her new wardrobe. T-shirts cost \$20 each and pants cost \$50 each. Joan has the following utility function $U(T, P) = 2T^{\frac{1}{4}} + 4P^{\frac{1}{3}}$. Use this information to answer questions 14-18.

14. How much utility does Joan derive from 10 t-shirts and 3 pairs of pants?
15. Joan currently has 16 t-shirts and 27 pairs of pants. She now knows she needs 256 t-shirts. How many pairs of pants does she need to be at least as well off as she is currently?
16. What is Joan's marginal utility of t-shirts?
17. What is Joan's marginal utility of pants?
18. What is Joan's marginal rate of substitution between t-shirts and pants?

For questions 19-23 consider Danica who is deciding between purchasing video games and music. Video games cost \$70 each and music (CDs) is \$20 each. Danica's preferences are represented by the following utility function $U(V, M) = 10V^{\frac{1}{2}} + 2M^2$.

19. What is Danica's marginal utility of video games?
20. What is Danica's marginal utility of music?
21. What is Danica's marginal rate of substitution between video games and music?
22. Does Danica have diminishing marginal utility in video games?
23. Does Danica have diminishing marginal utility in music?

Answers

1. $U(10, 26) = 3(10)^{1/6} + 2(26)^{1/4} = 3(1.468) + 2(2.258) \approx 4.404 + 4.516 \approx 8.92$
2. $U(25, 6) = 3(25)^{1/6} + 2(6)^{1/4} = 3(1.699) + 2(1.565) \approx 5.097 + 3.130 \approx 8.26$
3. $U(15, 18) = 3(15)^{1/6} + 2(18)^{1/4} = 3(1.570) + 2(2.060) \approx 4.710 + 4.120 \approx 8.83$
4. From questions 1–3: $U(10, 26) \approx 8.92 > U(15, 18) \approx 8.83 > U(25, 6) \approx 8.26$. Chase has the following ranking: (10 Cokes, 26 Powerades) $\succ$ (15 Cokes, 18 Powerades) $\succ$ (25 Cokes, 6 Powerades).
5. $U(64, 625) = 3(64)^{1/6} + 2(625)^{1/4} = 3(2) + 2(5) = 6 + 10 = 16$ and $U(4096, 16) = 3(4096)^{1/6} + 2(16)^{1/4} = 3(4) + 2(2) = 12 + 4 = 16$. Both bundles yield the same utility, so Chase is indifferent between the two. Thus these bundles lie on the same indifference curve.
6. Yes. Chase's preferences are complete since we can find the utility of any non-negative amount of Coke and Powerade (i.e. any bundle) and thus know Chase's preferences between any two bundles.
7. Yes. Chase's preferences are transitive. Because preferences are represented by a utility function, if $U(A) \geq U(B)$ and $U(B) \geq U(C)$, then it must follow that $U(A) \geq U(C)$.
8. Yes. Chase is rational. Rationality requires that preferences be both complete (question 6) and transitive (question 7). Since both conditions are satisfied, Chase's preferences are rational. Also, we know that Chase is rational since his preferences can be represented by a utility function.
9. $U(C, P) = 3C^{1/6} + 2P^{1/4} \Rightarrow MU_C = \frac{\partial U}{\partial C} = \frac{1}{6} \cdot 3C^{1/6-1} = \frac{1}{2}C^{-5/6}$
10. $U(C, P) = 3C^{1/6} + 2P^{1/4} \Rightarrow MU_P = \frac{\partial U}{\partial P} = \frac{1}{4} \cdot 2P^{1/4-1} = \frac{1}{2}P^{-3/4}$
11. Yes. $MU_C = \frac{1}{2}C^{-5/6} \Rightarrow \frac{\partial MU_C}{\partial C} = -\frac{5}{6} \cdot \frac{1}{2}C^{-11/6} = -\frac{5}{12}C^{-11/6} < 0$ for all $C > 0$
12. Yes. $MU_P = \frac{1}{2}P^{-3/4} \Rightarrow \frac{\partial MU_P}{\partial P} = -\frac{3}{4} \cdot \frac{1}{2}P^{-7/4} = -\frac{3}{8}P^{-7/4} < 0$ for all $P > 0$
13. $MRS_{C,P} = \frac{MU_C}{MU_P} = \frac{\frac{1}{2}C^{-5/6}}{\frac{1}{2}P^{-3/4}} = \frac{P^{3/4}}{C^{5/6}}$
14. $U(10, 3) = 2(10)^{1/4} + 4(3)^{1/3} = 2(1.778) + 4(1.442) \approx 3.557 + 5.770 \approx 9.33$
15. $U(16, 27) = 2(16)^{1/4} + 4(27)^{1/3} = 2(2) + 4(3) = 4 + 12 = 16$. Setting $U(256, P) = 16$: $2(256)^{1/4} + 4P^{1/3} = 16 \Rightarrow 2(4) + 4P^{1/3} = 16 \Rightarrow 4P^{1/3} = 8 \Rightarrow P^{1/3} = 2 \Rightarrow P = 8$. Joan needs at least 8 pairs of pants to be at least as well off as she is currently.
16. $U(T, P) = 2T^{1/4} + 4P^{1/3} \Rightarrow MU_T = \frac{\partial U}{\partial T} = \frac{1}{4} \cdot 2T^{1/4-1} = \frac{1}{2}T^{-3/4}$
17. $U(T, P) = 2T^{1/4} + 4P^{1/3} \Rightarrow MU_P = \frac{\partial U}{\partial P} = \frac{1}{3} \cdot 4P^{1/3-1} = \frac{4}{3}P^{-2/3}$
18. $MRS_{T,P} = \frac{MU_T}{MU_P} = \frac{\frac{1}{2}T^{-3/4}}{\frac{4}{3}P^{-2/3}} = \frac{1}{2} \cdot \frac{3}{4} \cdot \frac{P^{2/3}}{T^{3/4}} = \frac{3}{8} \cdot \frac{P^{2/3}}{T^{3/4}}$
19. $U(V, M) = 10V^{1/2} + 2M^2 \Rightarrow MU_V = \frac{\partial U}{\partial V} = \frac{1}{2} \cdot 10V^{1/2-1} = 5V^{-1/2}$
20. $U(V, M) = 10V^{1/2} + 2M^2 \Rightarrow MU_M = \frac{\partial U}{\partial M} = 2 \cdot 2M^{2-1} = 4M$
21. $MRS_{V,M} = \frac{MU_V}{MU_M} = \frac{5V^{-1/2}}{4M} = \frac{5}{4MV^{1/2}}$
22. Yes. $MU_V = 5V^{-1/2} \Rightarrow \frac{\partial MU_V}{\partial V} = -\frac{1}{2} \cdot 5V^{-3/2} = -\frac{5}{2}V^{-3/2} < 0$ for all $V > 0$, so Danica exhibits diminishing marginal utility in video games.
23. No. $MU_M = 4M \Rightarrow \frac{\partial MU_M}{\partial M} = 4 > 0$. Since each additional unit of music increases Danica's marginal utility, she exhibits increasing marginal utility in music, not diminishing. Notice this goes against our normal assumptions.

Consumer Choice

Larry has \$12 to purchase either hot dogs or hamburgers for his cookout. Hot dogs (D) cost \$1 and hamburgers (B) cost \$2. Larry's preferences are represented by the following utility function $U(D, B) = \sqrt{D} + \sqrt{B}$. Use this information to answer question 1 - 6.

1. What is Larry's marginal utility of hot dogs?
2. What is Larry's marginal utility of hamburgers?
3. What is Larry's marginal rate of substitution between hamburgers and hot dogs?
4. What is the slope of Larry's budget line?
5. Draw Larry's budget set.
6. What is Larry's optimal bundle?

Lauren has \$48 to purchase waffles, which cost \$3, and pancakes, which cost \$4, for a brunch party she is throwing. She has the utility function shown below. Use this information to answer questions 7-11.

$$U(W, P) = W^{\frac{1}{2}} + 2P^{\frac{1}{2}}$$

7. What is Lauren's marginal utility of waffles?
8. What is Lauren's marginal utility of pancakes?
9. Does Lauren have diminishing marginal utility in waffles? Pancakes?
10. What is Lauren's optimal bundle?
11. Draw Lauren's situation. Make sure to include her budget set, optimal bundle, and indifference curve.

Bill has \$126 to purchase pens and paper. Pens (PE) cost \$2 while paper (PA) costs \$9 per unit. Bill has the utility function below. Use this information to answer questions 12-15.

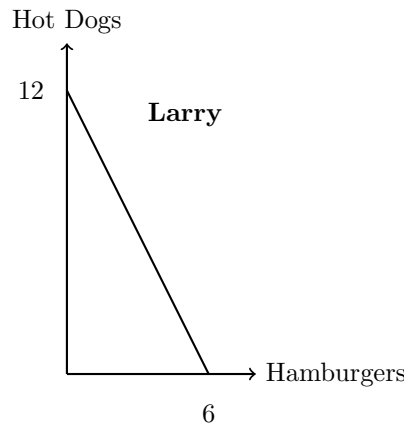
$$U(PE, PA) = PE^{\frac{1}{3}} + 2PA^{\frac{1}{3}}$$

12. What is Bill's optimal bundle?
13. What is Bill's marginal rate of substitution at his optimal bundle? Explain what this means in words.
14. Draw Bill's scenario. Make sure to include her budget set, optimal bundle, and indifference curve.
15. Suppose Bill chose to consume 8 pens and 1 piece of paper and suddenly has more income. Should Bill purchase more pens or paper?
16. Zoey has \$90 and currently buys 25 salads for \$3 each. The price of salads suddenly increases to \$10 and Zoey purchases 7 salads. At \$10 per salad, it Zoey could consume 17 salads and be just as well off.
 - A) Draw Zoey's scenario when salads cost \$3.
 - B) Draw Zoey's scenario when salads cost \$10.
 - C) What are the total, substitution, and income effects?
 - D) Is salad a normal or inferior good for Zoey?
17. Jacob has \$2,500. Towels currently cost \$5 each and Jacob buys 200 towels. The price of towels decreases to \$2.50 each and Jacob then buys 750 towels. Jacob could purchase 500 towels at the new price and be no better off than he was previously.
 - A) Illustrate Jacob's original situation.
 - B) Illustrate Jacob's scenario when towels cost \$2.50 each.
 - C) What are the total, substitution, and income effects for Jacob?
 - D) Are towels a normal or inferior good?

18. Sam has \$1,200 to purchase textbooks which cost \$40. Textbooks suddenly cost \$120 now.
- A) Draw Sam's scenario when textbooks are \$40.
 - B) Draw Sam's scenario when textbooks are \$120.
 - C) What is the total, substitution, and income effects? Use the values given in your own figure(s) and state if each effect is positive (> 0) or negative (< 0).
 - D) Based on your diagram(s), are textbooks a normal or inferior good?
19. Janet has \$400 to purchase either ham for \$5 per pound or turkey for \$4 per pound. Janet currently purchases 40 pounds of ham and 60 pounds of turkey. Suddenly, the price of ham decreases to \$2.50 per pound.
- A) Draw Janet's situation when she consumes 40 pounds of ham and 60 pounds of ham.
 - B) Draw Janet's situation when ham costs \$2.50 per pound.
 - C) Based off of your figure, what are the total, substitution, and income effects?
 - D) Based on your figure(s) answering the previous parts, is ham a normal or inferior good for Janet?

Answers

1. $U(D, B) = D^{1/2} + B^{1/2} \Rightarrow MU_D = \frac{\partial U}{\partial D} = \frac{1}{2}D^{-1/2} = \frac{1}{2\sqrt{D}}$
2. $U(D, B) = D^{1/2} + B^{1/2} \Rightarrow MU_B = \frac{\partial U}{\partial B} = \frac{1}{2}B^{-1/2} = \frac{1}{2\sqrt{B}}$
3. $MRS_{D,B} = \frac{MU_D}{MU_B} = \frac{\frac{1}{2\sqrt{D}}}{\frac{1}{2\sqrt{B}}} = \frac{\sqrt{B}}{\sqrt{D}}$
4. The slope of the budget line equals the negative price ratio: $-\frac{p_D}{p_B} = -\frac{1}{2}$
5. Larry's budget line is $D + 2B = 12$. The intercepts are $D = 12$ (spend all on hotdogs) and $B = 6$ (spend all on hamburgers). The budget set is all bundles on or below this line.



6. Set the optimality condition $\frac{MU_D}{p_D} = \frac{MU_B}{p_B}$ and solve simultaneously with the budget constraint.

Step 1

$$\begin{aligned} \frac{MU_D}{p_D} = \frac{MU_B}{p_B} &\Rightarrow \frac{\frac{1}{2\sqrt{D}}}{1} = \frac{\frac{1}{2\sqrt{B}}}{2} \Rightarrow \frac{1}{2\sqrt{D}} = \frac{1}{4\sqrt{B}} \Rightarrow 4\sqrt{B} = 2\sqrt{D} \Rightarrow \sqrt{D} = 2\sqrt{B} \\ &\Rightarrow D = 4B \end{aligned}$$

Step 2 (Substitute into budget constraint)

$$D + 2B = 12 \Rightarrow 4B + 2B = 12 \Rightarrow 6B = 12 \Rightarrow B^* = 2$$

$$D^* = 4B^* = 4(2) = 8$$

Larry's optimal bundle is $\boxed{D^* = 8 \text{ hotdogs, } B^* = 2 \text{ hamburgers}}$.

7. $U(W, P) = W^{1/2} + 2P^{1/2} \Rightarrow MU_W = \frac{\partial U}{\partial W} = \frac{1}{2}W^{-1/2} = \frac{1}{2\sqrt{W}}$
8. $U(W, P) = W^{1/2} + 2P^{1/2} \Rightarrow MU_P = \frac{\partial U}{\partial P} = 2 \cdot \frac{1}{2}P^{-1/2} = \frac{1}{\sqrt{P}}$
9. Yes to both. For waffles: $\frac{\partial MU_W}{\partial W} = -\frac{1}{4}W^{-3/2} < 0$ for all $W > 0$, so Lauren has diminishing marginal utility in waffles. For pancakes: $\frac{\partial MU_P}{\partial P} = -\frac{1}{2}P^{-3/2} < 0$ for all $P > 0$, so Lauren also has diminishing marginal utility in pancakes.
10. Set the optimality condition $\frac{MU_W}{p_W} = \frac{MU_P}{p_P}$ and solve simultaneously with the budget constraint.

Step 1

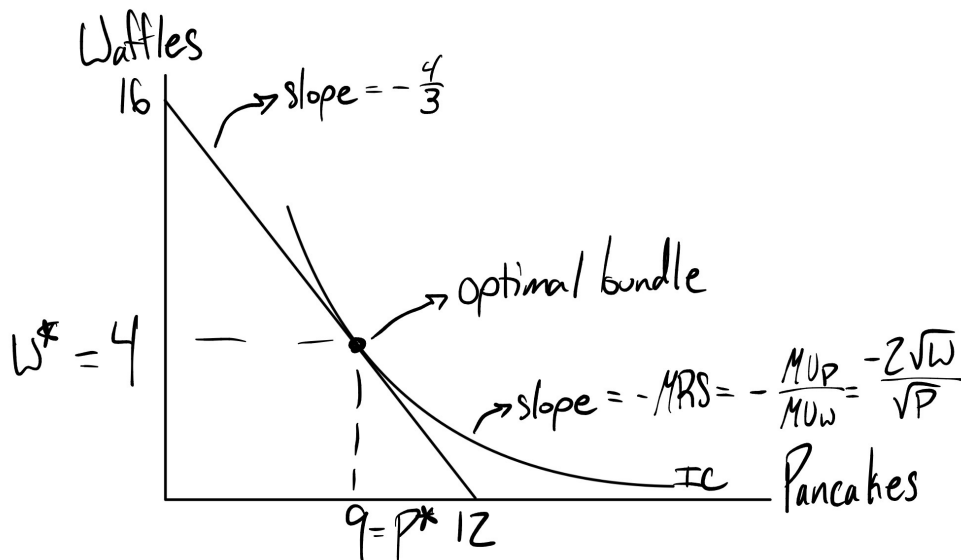
$$\begin{aligned} \frac{MU_W}{p_W} = \frac{MU_P}{p_P} &\Rightarrow \frac{\frac{1}{2\sqrt{W}}}{3} = \frac{\frac{1}{\sqrt{P}}}{4} \Rightarrow \frac{1}{6\sqrt{W}} = \frac{1}{4\sqrt{P}} \Rightarrow 4\sqrt{P} = 6\sqrt{W} \Rightarrow \sqrt{P} = \frac{3}{2}\sqrt{W} \\ &\Rightarrow P = \frac{9}{4}W \end{aligned}$$

Step 2 (Substitute into budget constraint)

$$\begin{aligned} 3W + 4P = 48 &\Rightarrow 3W + 4\left(\frac{9}{4}W\right) = 48 \Rightarrow 3W + 9W = 48 \Rightarrow 12W = 48 \Rightarrow W^* = 4 \\ P^* = \frac{9}{4}W^* &= \frac{9}{4}(4) = 9 \end{aligned}$$

Lauren's optimal bundle is $\boxed{W^* = 4 \text{ waffles}, P^* = 9 \text{ pancakes}}$.

11. Lauren's budget line is $3W + 4P = 48$, with intercepts at $W = 16$ and $P = 12$. Plot the budget line, mark the optimal bundle (4, 9), and draw the indifference curve $W^{1/2} + 2P^{1/2} = 4^{1/2} + 2(9)^{1/2} = 2 + 6 = 8$ tangent to the budget line at that point.



12. Set the optimality condition $\frac{MU_{PE}}{p_{PE}} = \frac{MU_{PA}}{p_{PA}}$ and solve simultaneously with the budget constraint.

Step 1

$$\begin{aligned} \frac{MU_{PE}}{p_{PE}} = \frac{MU_{PA}}{p_{PA}} &\Rightarrow \frac{\frac{1}{3}PE^{-2/3}}{2} = \frac{\frac{2}{3}PA^{-2/3}}{9} \Rightarrow \frac{PE^{-2/3}}{6} = \frac{2PA^{-2/3}}{27} \Rightarrow 27PE^{-2/3} = 12PA^{-2/3} \\ &\Rightarrow \frac{PA^{-2/3}}{PE^{-2/3}} = \frac{27}{12} = \frac{9}{4} \Rightarrow \left(\frac{PE}{PA}\right)^{2/3} = \frac{9}{4} \Rightarrow \frac{PE}{PA} = \left(\frac{9}{4}\right)^{3/2} = \frac{27}{8} \Rightarrow PE = \frac{27}{8}PA \end{aligned}$$

Step 2 (Substitute into budget constraint)

$$2PE + 9PA = 126 \Rightarrow 2\left(\frac{27}{8}PA\right) + 9PA = 126 \Rightarrow \frac{27}{4}PA + 9PA = 126 \Rightarrow \frac{63}{4}PA = 126 \Rightarrow PA^* = 8$$

$$PE^* = \frac{27}{8}(8) = 27$$

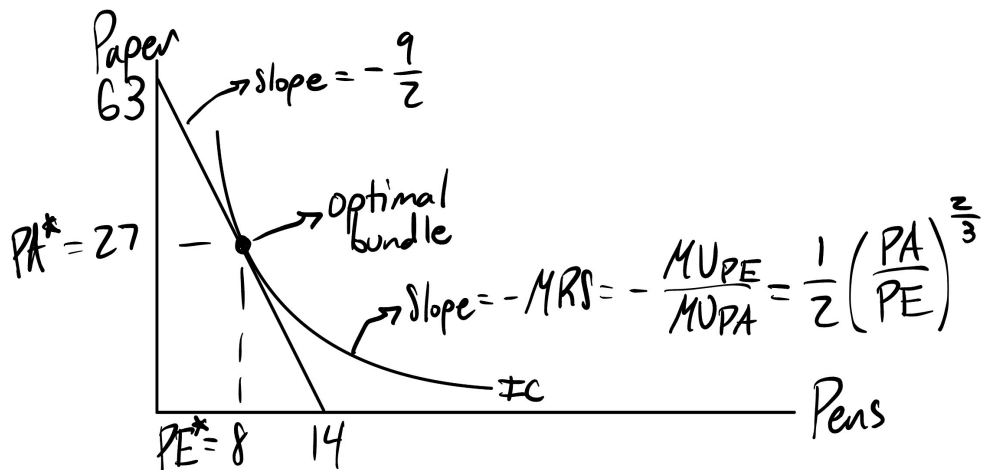
Bill's optimal bundle is $PE^* = 27$ pens, $PA^* = 8$ units of paper.

13. $MRS_{PE,PA} = \frac{MU_{PE}}{MU_{PA}}$. Evaluating at the optimal bundle $(PE^*, PA^*) = (27, 8)$:

$$\begin{aligned} MU_{PE} &= \frac{1}{3}(27)^{-2/3} = \frac{1}{3} \cdot \frac{1}{9} = \frac{1}{27}, & MU_{PA} &= \frac{2}{3}(8)^{-2/3} = \frac{2}{3} \cdot \frac{1}{4} = \frac{1}{6} \\ MRS &= \frac{1/27}{1/6} = \frac{1}{27} \cdot 6 = \frac{6}{27} = \frac{2}{9} \end{aligned}$$

At the optimum, $MRS = p_{PE}/p_{PA} = 2/9$. In words: at his optimal bundle, Bill is willing to give up $\frac{2}{9}$ of a unit of paper for one additional pen, which is exactly the market exchange rate, thus he has no incentive to deviate.

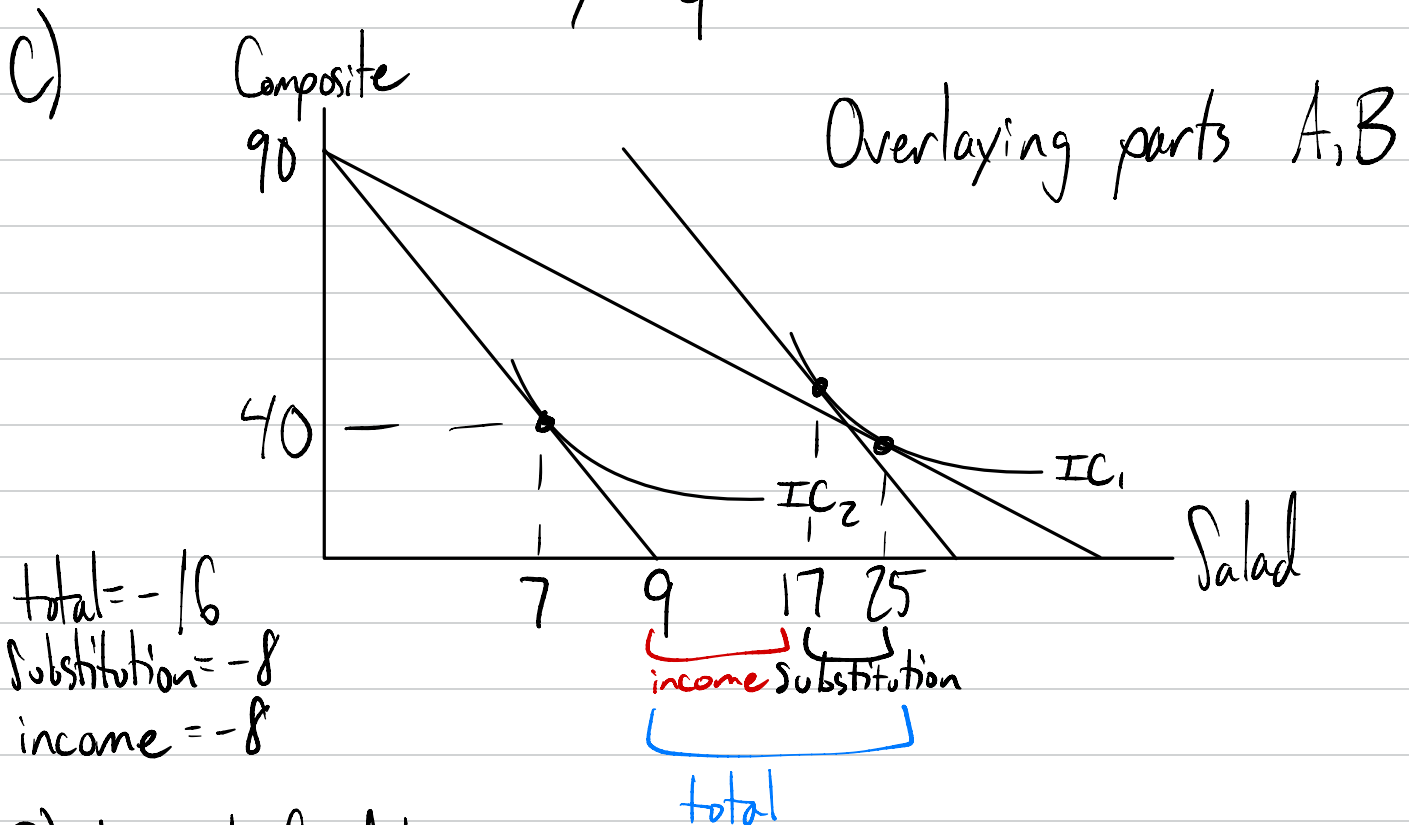
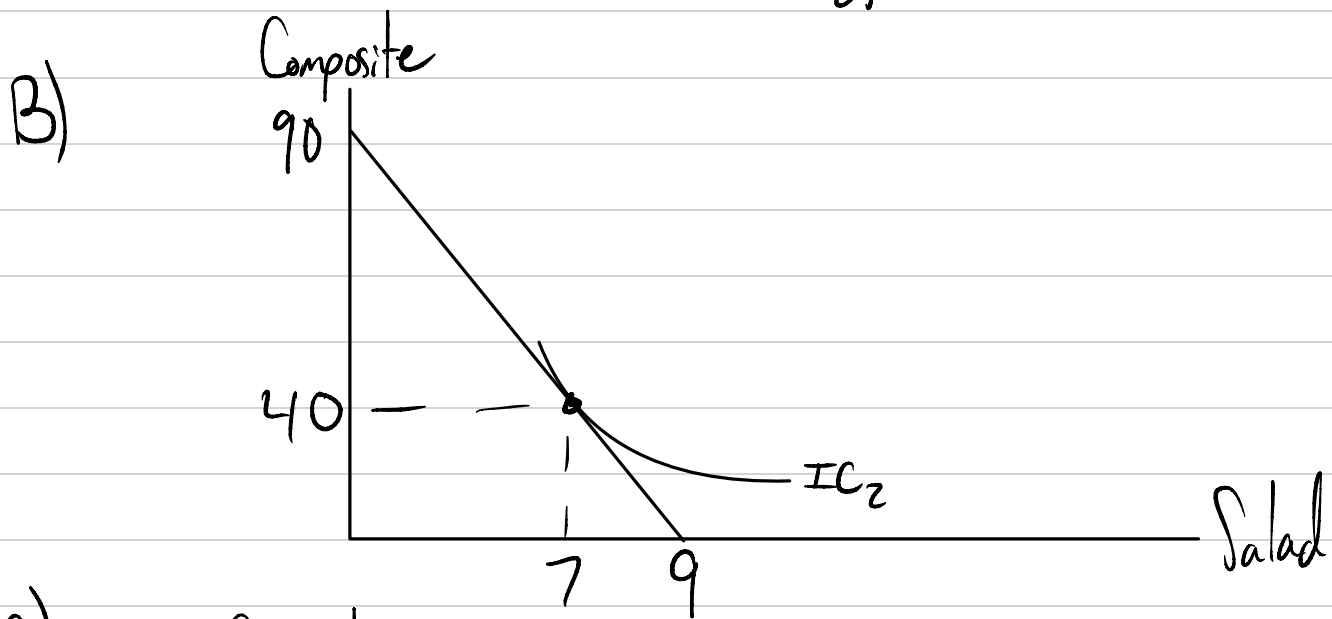
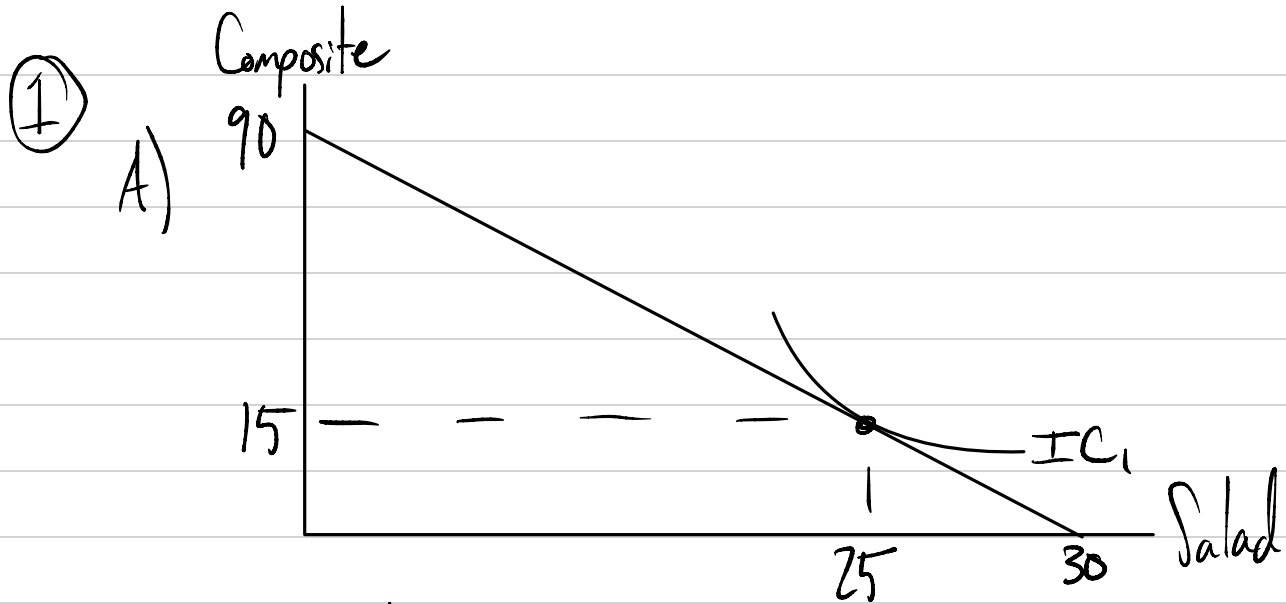
14. Bill's budget line is $2PE + 9PA = 126$, with intercepts at $PE = 63$ and $PA = 14$. Plot the budget line, mark the optimal bundle $(27, 8)$, and draw the indifference curve $PE^{1/3} + 2PA^{1/3} = 27^{1/3} + 2(8)^{1/3} = 3 + 4 = 7$ tangent to the budget line at that point.



15. At the bundle $(PE, PA) = (8, 1)$...

$$\begin{aligned} MU_{PE} &= \frac{1}{3}(8)^{-2/3} = \frac{1}{3} \cdot \frac{1}{4} = \frac{1}{12}, & MU_{PA} &= \frac{2}{3}(1)^{-2/3} = \frac{2}{3} \\ \frac{MU_{PE}}{p_{PE}} &= \frac{1/12}{2} = \frac{1}{24}, & \frac{MU_{PA}}{p_{PA}} &= \frac{2/3}{9} = \frac{2}{27} \end{aligned}$$

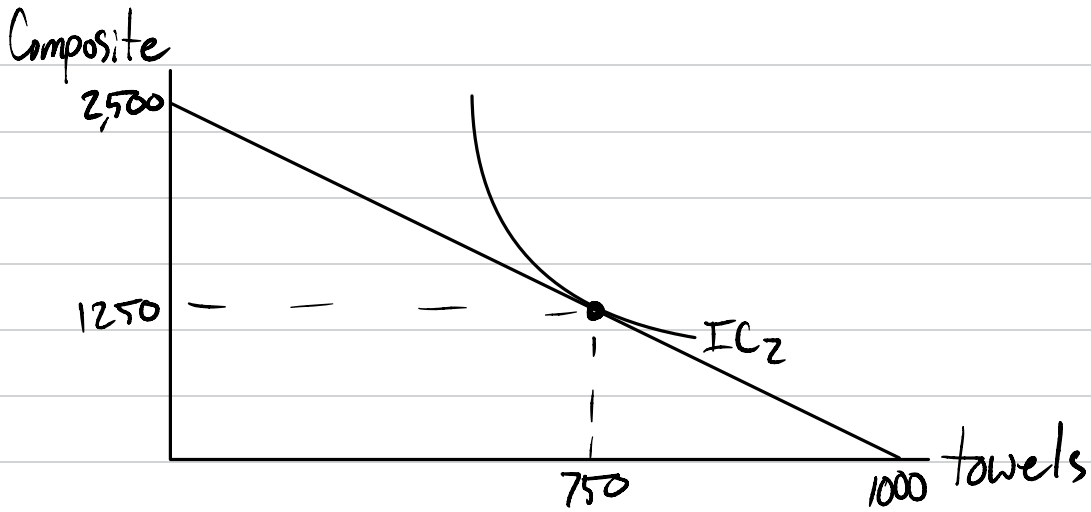
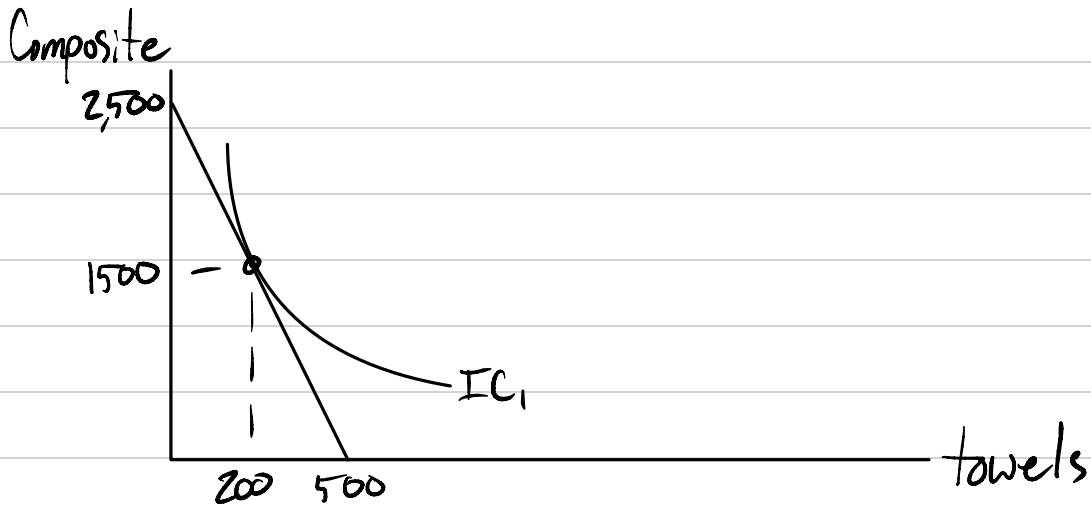
Since $\frac{2}{27} > \frac{1}{24}$, Bill gets more utility per dollar from paper than from pens at this bundle. He should spend his additional income on paper.



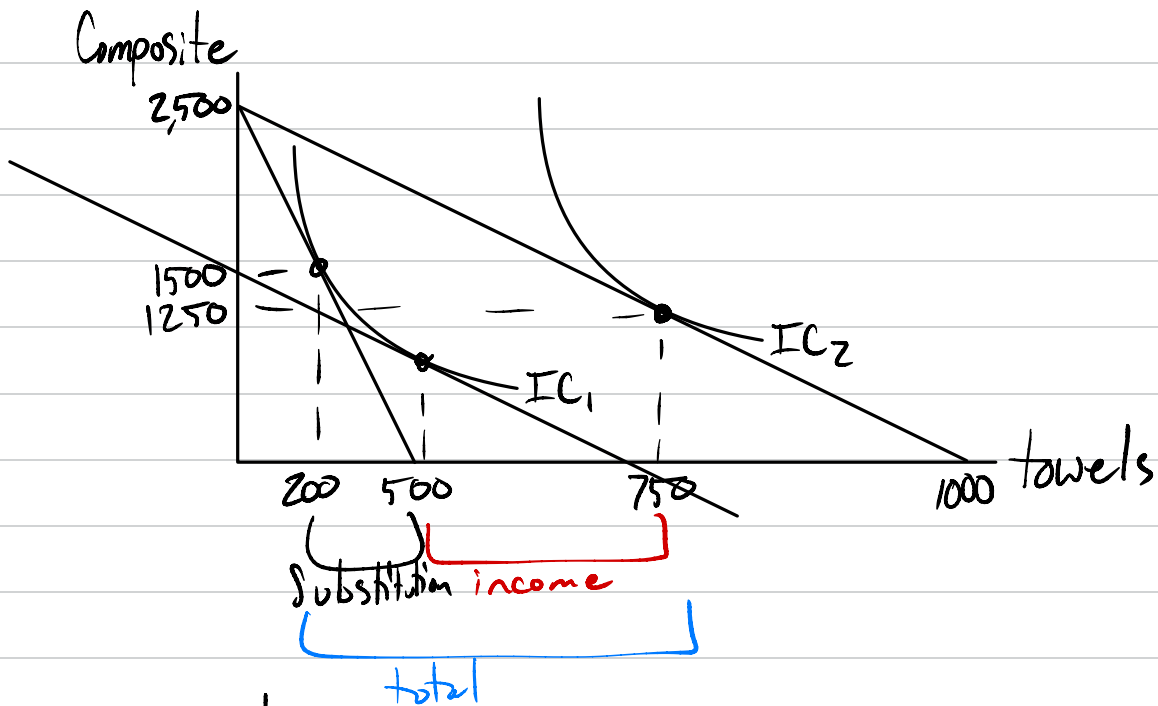
D) Normal Good!

②

A)



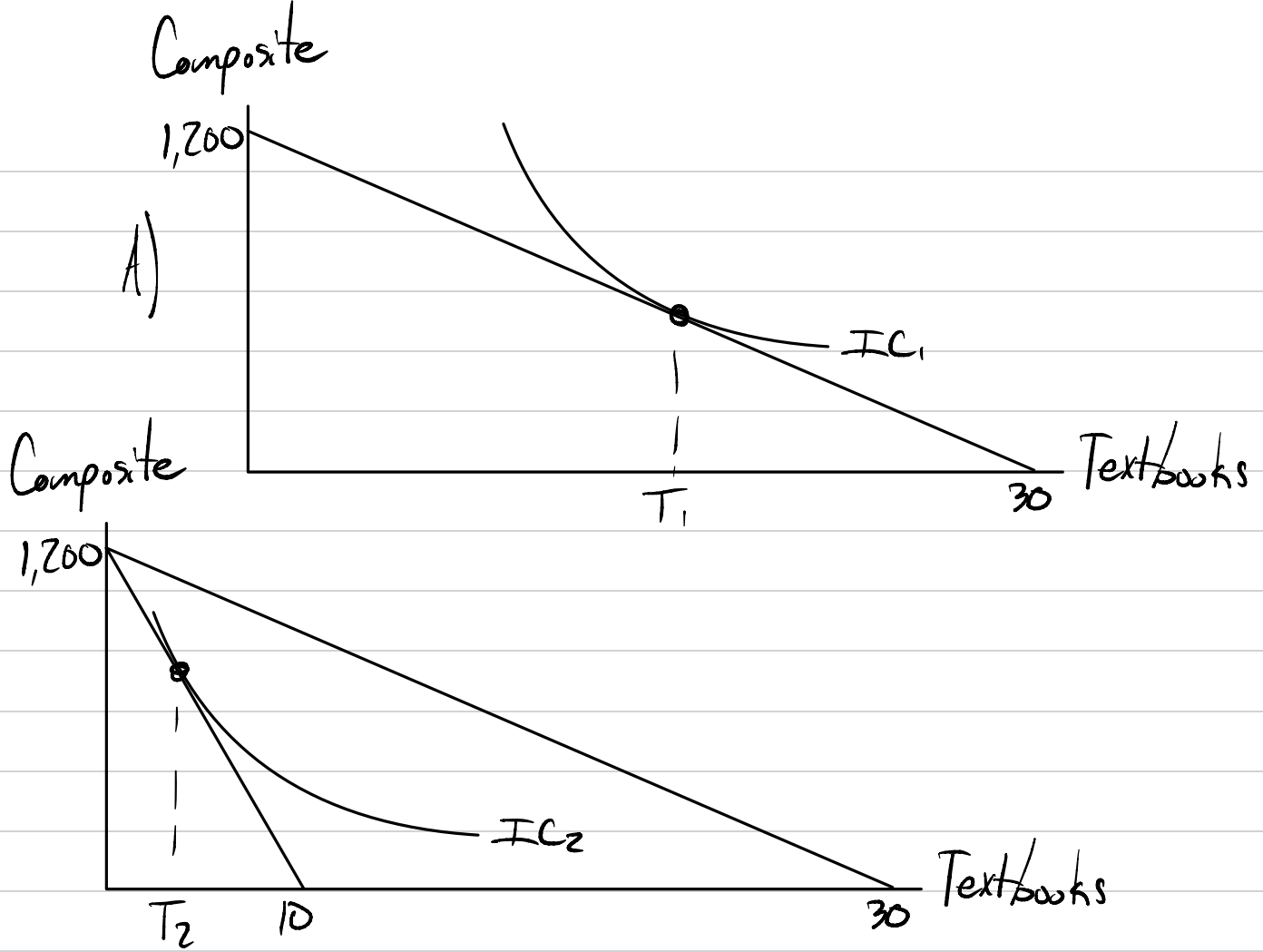
C)



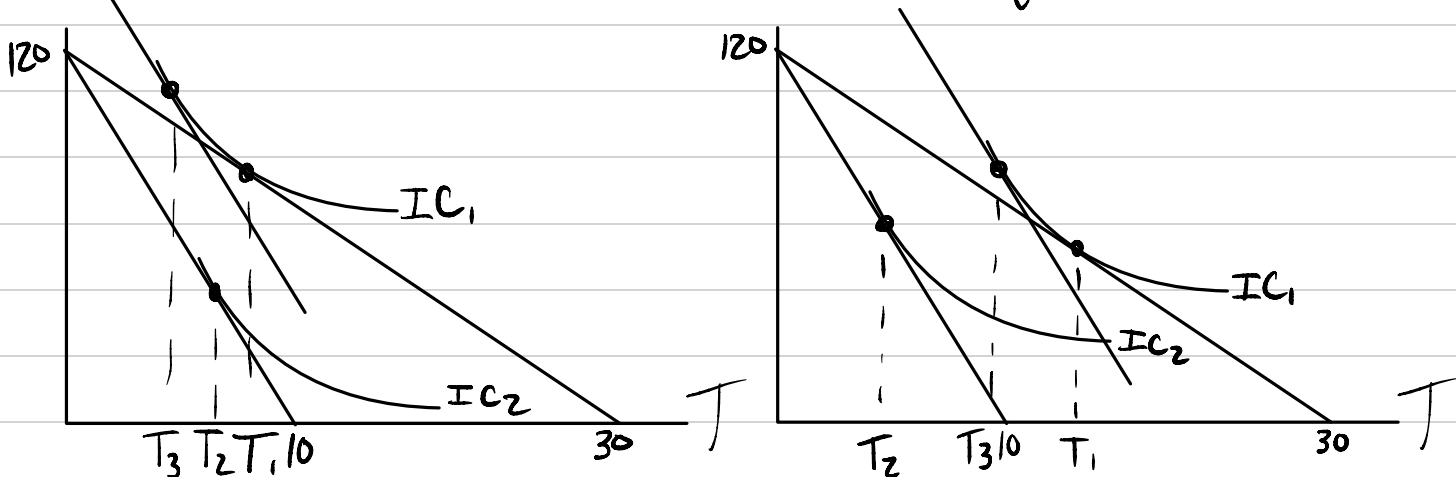
Total = 550, Substitution = 300, Income = 250

D) Normal Good!

3



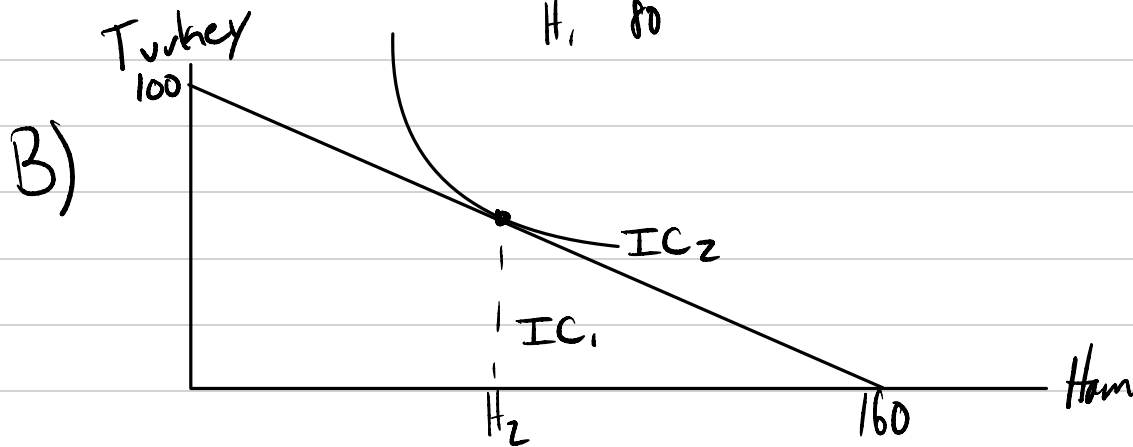
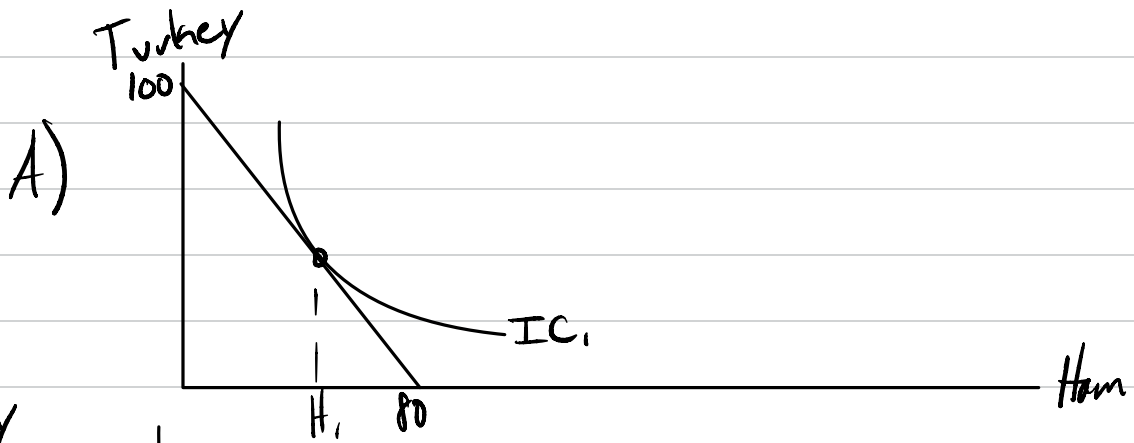
C) Problems C and D vary depending on how you draw it. I show a version where textbooks are a normal good and another where they are an inferior good.



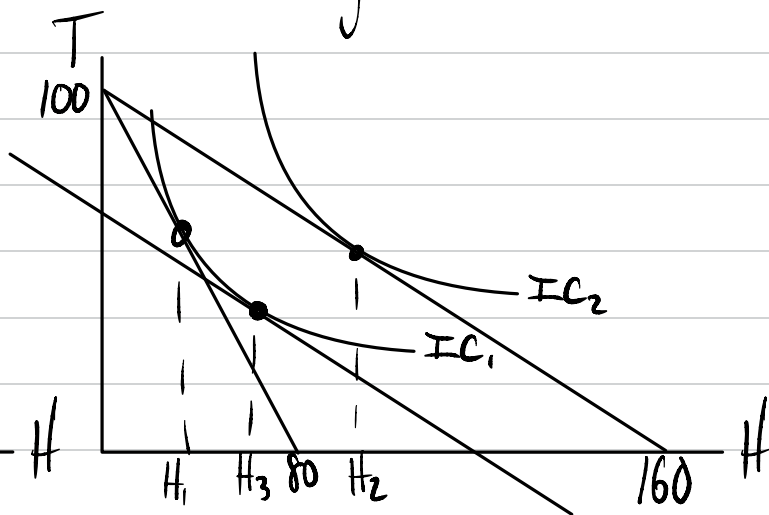
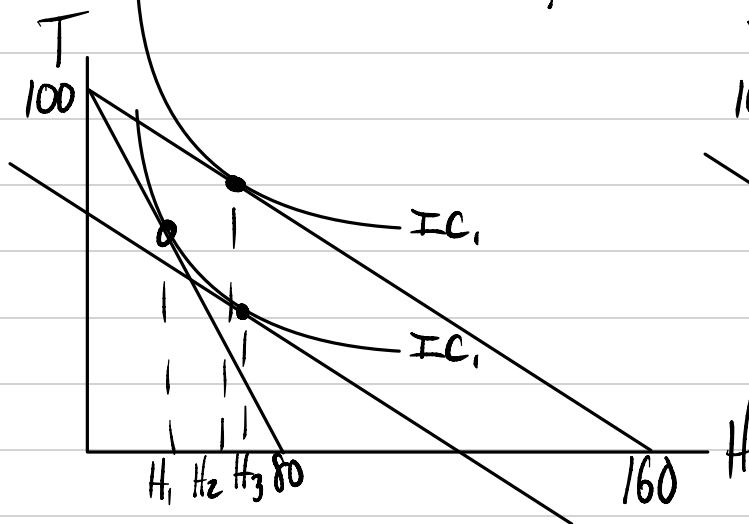
$$\begin{aligned} \text{Total} &= T_2 - T_1 < 0 \\ \text{Sub} &= T_3 - T_1 < 0 \\ \text{Inc} &= T_2 - T_3 > 0 \\ &\Rightarrow \text{Inferior!} \end{aligned}$$

$$\begin{aligned} T_2 - T_1 &< 0 \\ T_3 - T_1 &< 0 \\ T_2 - T_3 &< 0 \\ &\Rightarrow \text{Normal!} \end{aligned}$$

4



C) Problems C and D vary depending on how you draw it. I show a version where ham is a normal good and another where they are an inferior good.



$$\begin{aligned} \text{Total} &= H_2 - H_1 > 0 \\ \text{Sub} &= H_3 - H_1 > 0 \\ \text{Inc} &= H_3 - H_2 < 0 \\ &\Rightarrow \text{Inferior} \end{aligned}$$

$$\begin{aligned} H_2 - H_1 &> 0 \\ H_3 - H_1 &> 0 \\ H_2 - H_3 &> 0 \\ &\Rightarrow \text{Normal} \end{aligned}$$

Production

A firm needs to produce 7 widgets. They have the production function below and are subject to a rental rate of \$3 and wage rate of \$4 per hour. Use this information to answer questions 1-4.

$$Q = K^{\frac{1}{2}} + L^{\frac{1}{2}}$$

1. What is this firm's marginal product of labor and capital?
2. What amount of capital and labor should this firm employ?
3. What is the minimum cost to produce 7 widgets?
4. Illustrate this situation.

I make birdhouses using my labor and a drill. I want to make 5 birdhouses a week. I rent the drill for \$4 a week and my labor is valued at \$9 a week. My production function is below. Use this information to answer questions 5-8.

$$Q = K^{\frac{1}{3}} + L^{\frac{1}{3}}$$

5. What is my marginal rate of technical substitution?
6. What is my optimal amount of drill hours and labor?
7. How much does the combination of drill hours and labor you found in question 6 cost?
8. Is the input bundle you stated in question 6 considered to be a corner solution?

Apple wants to make 19 watches. They have the production function below and are subject to a rental rate of capital equal to \$3 and a \$5 wage rate. Use this information to answer questions 9-13.

$$Q = 3K^{\frac{1}{2}} + 2L^{\frac{1}{2}}$$

9. What is Apple's marginal product of labor and capital?
10. What is Apple's marginal rate of technical substitution?
11. What is Apple's optimal input bundle?
12. What is the minimum cost of 19 Apple watches?
13. Illustrate Apple's production of watches.

Production 1

$$\textcircled{1} \quad MP_L = \frac{1}{2} K^{-\frac{1}{2}} \quad \Rightarrow \quad MRTS = \frac{\frac{1}{2} L^{-\frac{1}{2}}}{\frac{1}{2} K^{-\frac{1}{2}}} = \left(\frac{K}{L}\right)^{\frac{1}{2}}$$
$$MP_K = \frac{1}{2} L^{-\frac{1}{2}}$$

$$\textcircled{2} \quad \frac{MP_L}{w} = \frac{MP_K}{r} \quad \Rightarrow \quad \frac{\frac{1}{2} L^{-\frac{1}{2}}}{4} = \frac{\frac{1}{2} K^{-\frac{1}{2}}}{3}$$

$$\Rightarrow \frac{3}{4} L^{-\frac{1}{2}} = K^{-\frac{1}{2}}$$

$$\Rightarrow K = \frac{16}{9} L$$

$$Q = K^{\frac{1}{2}} + L^{\frac{1}{2}} \Rightarrow 7 = \left(\frac{16}{9} L\right)^{\frac{1}{2}} + L^{\frac{1}{2}} = \frac{4}{3} L^{\frac{1}{2}} + L^{\frac{1}{2}} = \frac{7}{3} L^{\frac{1}{2}}$$

$$\Rightarrow L^{\frac{1}{2}} = 3$$

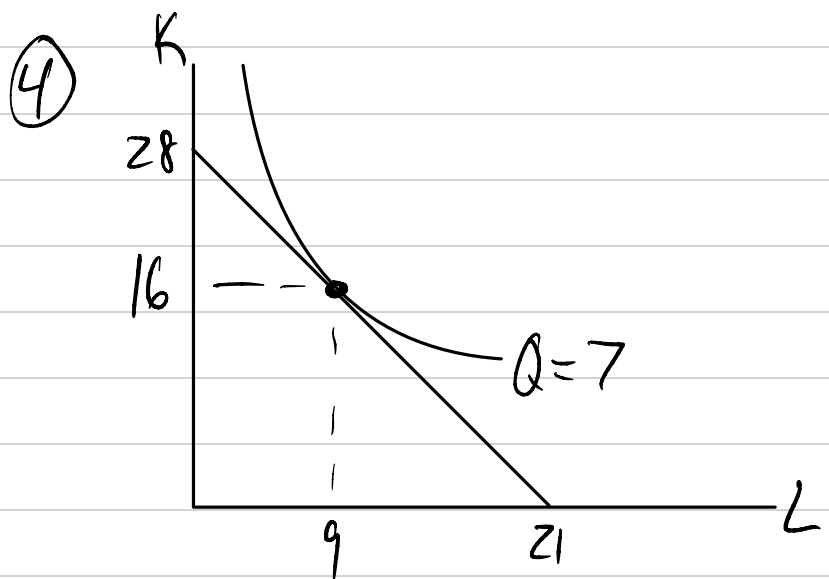
$$\Rightarrow \boxed{L^* = 9}$$

$$\Rightarrow \boxed{K^* = 16}$$

$$\textcircled{3} \quad C = wL + rK$$

$$\Rightarrow C = 4 \cdot 9 + 3 \cdot 16$$

$$\Rightarrow \boxed{C = \$84}$$



$$\textcircled{5} \quad MP_K = \frac{1}{3}K^{-\frac{2}{3}} \quad MP_L = \frac{1}{3}L^{-\frac{2}{3}} \Rightarrow MRTS = \frac{\cancel{\frac{1}{3}}L^{-\frac{2}{3}}}{\cancel{\frac{1}{3}}K^{-\frac{2}{3}}} = \boxed{\left(\frac{K}{L}\right)^{\frac{2}{3}}}$$

$$\textcircled{6} \quad MRTS = \left(\frac{K}{L}\right)^{\frac{2}{3}} = \frac{9}{4} = \frac{w}{r} = -\text{slope of BL}$$

$$\Rightarrow \frac{K}{L} = \frac{27}{8} \quad \Rightarrow 5 = \left(\frac{27}{8}L\right)^{\frac{1}{3}} + L^{\frac{1}{3}} = \frac{5}{2}L^{\frac{1}{3}}$$

$$\Rightarrow K = \frac{27}{8}L$$

$$\Rightarrow L^* = 8$$

$$\Rightarrow K^* = 27$$

$$\textcircled{7} \quad C = wL + rK$$

$$\Rightarrow C = 9 \cdot 8 + 4 \cdot 27 = \boxed{\$180}$$

$\textcircled{8}$ No since $L^* > 0$ and $K^* > 0$

$$\textcircled{9} \quad \begin{aligned} MP_K &= \frac{3}{2} K^{-\frac{1}{2}} \\ MP_L &= L^{-\frac{1}{2}} \end{aligned}$$

$$\textcircled{10} \quad MRTS = \frac{MP_L}{MP_K} = \frac{L^{-\frac{1}{2}}}{\frac{3}{2} K^{-\frac{1}{2}}} = \frac{2}{3} \left(\frac{K}{L} \right)^{\frac{1}{2}}$$

$$\textcircled{11} \quad MRTS = \frac{2}{3} \left(\frac{K}{L} \right)^{\frac{1}{2}} = \frac{5}{8} = \frac{w}{r}$$

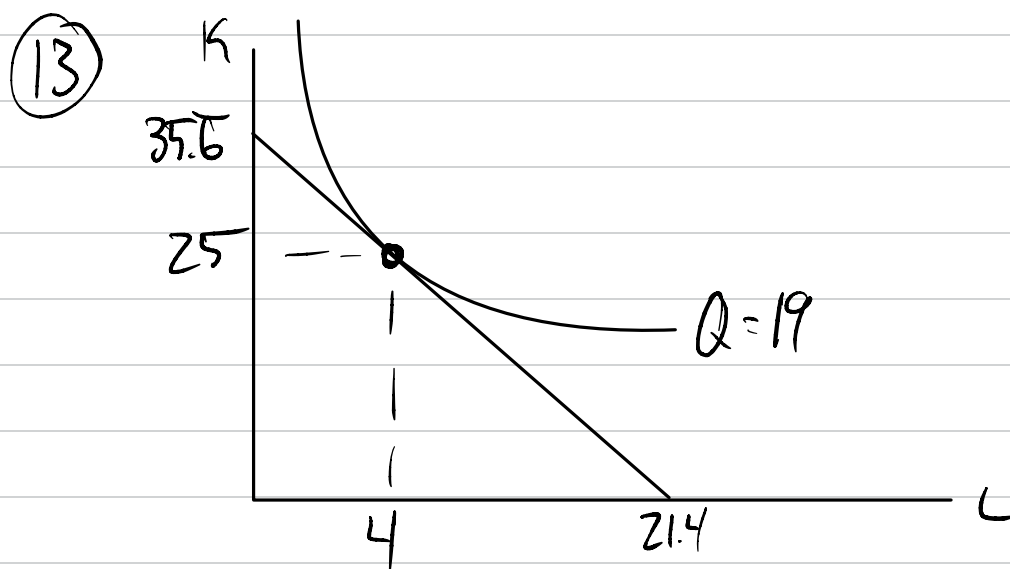
$$\Rightarrow K = \frac{25}{4} L$$

$$\Rightarrow 19 = 3 \left(\frac{25}{4} L \right)^{\frac{1}{2}} + 2L^{\frac{1}{2}} = \frac{19}{2} L^{\frac{1}{2}}$$

$$\Rightarrow L^* = 4$$

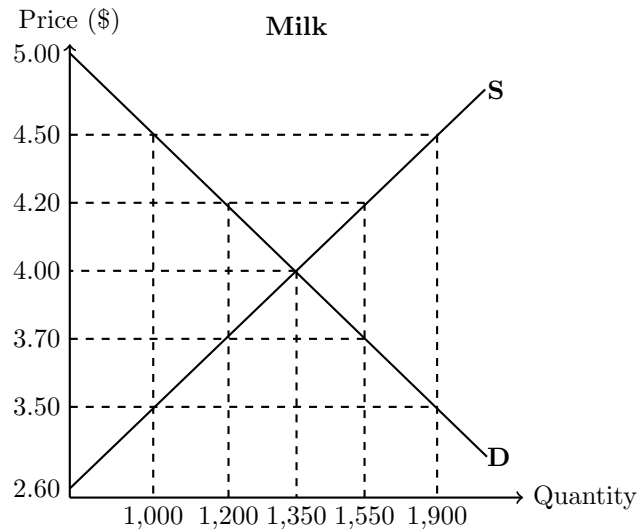
$$\Rightarrow K^* = 25$$

$$\textcircled{12} \quad C = 5 \cdot 4 + 3 \cdot 25 = \$107$$



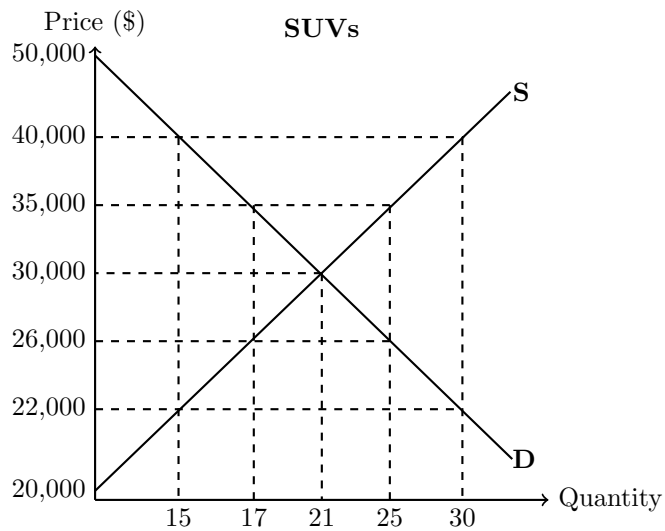
Taxes

Use the following graph representing the market for milk to answer questions 1-9.



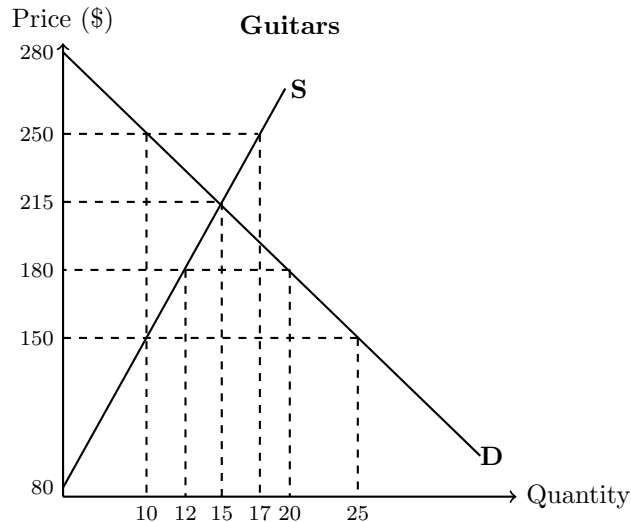
1. Draw and label the consumer surplus, producer surplus, and deadweight loss in this market when it operates at equilibrium.
2. Suppose the government imposes a \$0.50 tax per gallon of milk which is paid by consumers. Who has the statutory incidence? Who has the actual incidence?
3. Suppose the government imposes a \$0.50 tax per gallon of milk which is paid by consumers. What is the new quantity which is transacted in this market?
4. Suppose the government imposes a \$0.50 tax per gallon of milk which is paid by consumers. What is the effective price that consumers pay for milk?
5. Suppose the government imposes a \$0.50 tax per gallon of milk which is paid by consumers. What is the effective price that producers receive for milk?
6. Suppose the government imposes a \$0.50 tax per gallon of milk which is paid by consumers. Draw and label the new consumer surplus, producer surplus, and deadweight loss for this market.
7. Suppose the government imposes a \$0.50 tax per gallon of milk which is paid by consumers. Draw and label the lost consumer surplus due to this tax.
8. Suppose the government imposes a \$0.50 tax per gallon of milk which is paid by consumers. Draw and label the lost producer surplus due to this tax.
9. Suppose the government imposes a \$0.50 tax per gallon of milk which is paid by consumers. How much tax revenue is generated due to this tax?

Use the following graph representing the market for (new) SUVs to answer questions 10-15.



10. Draw and label the consumer surplus, producer surplus, and deadweight loss in this market when it operates at equilibrium.
11. The government enacts a \$9,000 subsidy on each SUV sold. This subsidy goes to the consumers of SUVs in the form of a tax refund. Who has the statutory incidence? Who has the actual incidence?
12. The government enacts a \$9,000 subsidy on each SUV sold. This subsidy goes to the consumers of SUVs in the form of a tax refund. What is the new quantity in this market?
13. The government enacts a \$9,000 subsidy on each SUV sold. This subsidy goes to the consumers of SUVs in the form of a tax refund. Draw and label the new consumer surplus, producer surplus, expenditure, and deadweight loss for this market.
14. The government enacts a \$9,000 subsidy on each SUV sold. This subsidy goes to the consumers of SUVs in the form of a tax refund. Draw and label the additional consumer surplus and producer surplus due to this subsidy.
15. The government enacts a \$9,000 subsidy on each SUV sold. This subsidy goes to the consumers of SUVs in the form of a tax refund. How much does this subsidy cost?

Use the following graph representing the market for guitars to answer questions 16-23.



16. Draw and label the consumer surplus, producer surplus, tax revenue, and deadweight loss in this market without a tax.
17. The government imposes a \$100 tax on guitars which is paid by the consumer as additional taxes due when they file on April 15th. Who has the statutory incidence? Who has the actual incidence?
18. The government imposes a \$100 tax on guitars which is paid by the consumer as additional taxes due when they file on April 15th. How many units will be transacted in this market after the tax has gone into effect?
19. The government imposes a \$100 tax on guitars which is paid by the consumer as additional taxes due when they file on April 15th. Draw and label the new consumer surplus, producer surplus, tax revenue, and deadweight loss for this market.
20. The government imposes a \$100 tax on guitars which is paid by the consumer as additional taxes due when they file on April 15th. Draw and label the gain or loss in consumer surplus due to the tax.
21. The government imposes a \$100 tax on guitars which is paid by the consumer as additional taxes due when they file on April 15th. How much tax revenue is generated?
22. The government imposes a \$100 tax on guitars which is paid by the consumer as additional taxes due when they file on April 15th. Solve for the loss in consumer surplus and producer surplus. What does this tell us about the relative elasticity of supply and demand in the market for guitars?
23. The government imposes a \$100 tax on guitars which is paid by the consumer as additional taxes due when they file on April 15th. How much dead weight loss is generated due to this tax?
24. The government must raise \$1,000 by taxing two goods. Good 1 has a price elasticity of demand of $\varepsilon_1 = 0.6$ and Good 2 has $\varepsilon_2 = 1.8$. What is the optimal ratio of tax rates t_1/t_2 for revenue generating purposes only?
25. The government may tax only handbags with $\varepsilon_1 = 1.6$ and airline tickets which have $\varepsilon_2 = 1.2$. How much more should airline tickets be taxed than handbags? If the tax on airline tickets is \$30, what should the tax on designer handbags be? Are these excise or ad valorem taxes?
26. A state needs to raise \$3,000 and may tax dental visits and gym memberships. Dental visits (Good 1) have $\varepsilon_1 = 0.7$, a pre-tax price of \$80, and 200 visits occur. Gym memberships (Good 2) have $\varepsilon_2 = 1.1$, a pre-tax price of \$50, and 300 memberships are sold. Find the optimal per-unit tax rates.
27. A city must raise \$2,200 and can do so by taxing two goods. Rideshare trips (Good 1) have $\varepsilon_1 = 1.3$, a price of \$12, and $Q_1 = 600$. Craft beer (Good 2) has $\varepsilon_2 = 1.6$, a price of \$8, and $Q_2 = 500$.
 - (a) Find the optimal per-unit tax rates.
 - (b) How does the revenue from the optimal tax you found in part (a) compare to a \$2 tax on all units of both goods?
 - (c) Why is the tax in part (a) optimal but not the one in part (b)?

Answers

1. Consumers (i.e. the demand side of the market) have the statutory incidence since they are the ones legally required to pay the tax. Both sides of the market (producers and consumers) have the actual incidence since both will pay a portion of the tax revenue (You solve for this in problem 8).
2. 1,200
3. \$4.20
4. \$3.70
5. $CS^e = \frac{1}{2} \times \$1 \times 1,350 = \$675$
 $CS^{tax} = \frac{1}{2} \times \$0.80 \times 1,200 = \$480$
 $CS^e - CS^{tax} = \$675 - \$480 = \$195$ worse off
6. $PS^e = \frac{1}{2} \times \$1.40 \times 1,350 = \$945$
 $PS^{tax} = \frac{1}{2} \times \$1.10 \times 1,200 = \$660$
 $PS^e - PS^{tax} = \$945 - \$660 = \$285$ worse off
7. $\$0.50 \times 1,200 = \600 in tax revenue
8. $\$0.20 \times 1,200 = \240 comes from consumers
 $\$0.30 \times 1,200 = \360 comes from producers
9. Since the producers pay more in tax revenue, we know that the demand for milk is more elastic than the supply of milk.
10. $DWL = \frac{1}{2} \times \$0.50 \times 150 = \$37.50$
11. Market Quantity (Q^*): 25
Quantity Supplied (Q_s): 25
Quantity Demanded (Q_d): 25
12. \$26,000
13. \$35,000
14. $CS^e = \frac{1}{2} \times \$20,000 \times 21 = \$210,000$
 $CS^{subsidy} = \frac{1}{2} \times \$24,000 \times 25 = \$300,000$
 $CS^{subsidy} - CS^e = \$300,000 - \$210,000 = \$90,000$ better off
15. $PS^e = \frac{1}{2} \times \$10,000 \times 21 = \$105,000$
 $PS^{subsidy} = \frac{1}{2} \times \$15,000 \times 25 = \$187,500$
 $PS^{subsidy} - PS^e = \$187,500 - \$105,000 = \$82,500$ better off
16. $\$9,000 \times 25 = \$225,000$ cost to the government
17. $\$4,000 \times 25 = \$100,000$ goes to the consumers of SUVs
 $\$5,000 \times 25 = \$125,000$ goes to the producers of SUVs
18. Since most of the money went to the the producers, supply is more inelastic than demand in this market.
19. $DWL = \frac{1}{2} \times \$9,000 \times 4 = \$18,000$
20. The consumer has the statutory incidence of this tax since they are the one required to pay it. Both consumers and producers of guitars will bear the actual incidence since they will have to bear the burden of the tax.
21. 10 units

22. $CS^e = \frac{1}{2} \times \$65 \times 15 = \$487.50$
 $CS^{tax} = \frac{1}{2} \times \$30 \times 10 = \$150$
 $CS^e - CS^{tax} = \$487.50 - \$150 = \$337.50$ worse off (consumers)
 $PS^e = \frac{1}{2} \times \$135 \times 15 = \$1,012.50$
 $PS^{tax} = \frac{1}{2} \times \$70 \times 10 = \$350$
 $PS^e - PS^{tax} = \$1,012.50 - \$350 = \$662.50$ worse off (producers)
23. $\$100 \times 10 = \$1,000$ in tax revenue is generated
 $\$45 \times 10 = \450 comes from consumers
 $\$55 \times 10 = \550 comes from producers
24. Since more of the actual incidence is on producers (i.e. they pay more of the tax), supply is more inelastic than demand in this market. Notice that you can actually see this in the graph representing this market.
25. $DWL = \frac{1}{2} \times \$100 \times 15 = \$750$
26. The Ramsey rule states that the optimal tax ratio is inversely proportional to the elasticity ratio:

$$\frac{t_1}{t_2} = \frac{\varepsilon_2}{\varepsilon_1} = \frac{1.8}{0.6} = 3$$

Good 1 should be taxed at three times the rate of Good 2. Since Good 1 is less elastic, consumers reduce quantity demanded less in response to the tax, resulting in less deadweight loss per dollar of revenue raised.

27. The Ramsey rule gives:

$$\frac{t_1}{t_2} = \frac{\varepsilon_2}{\varepsilon_1} = \frac{1.2}{1.6} = 0.75$$

Airline tickets should be taxed at 0.75 times the rate of handbags, meaning handbags should actually be taxed *more* than airline tickets because handbags are the more elastic good. With $t_1 = 0.75 \cdot t_2$ and $t_2 = \$30$:

$$t_1 = 0.75 \times \$30 = \$22.50$$

These are excise taxes (per-unit taxes) because they are fixed dollar amounts per unit sold rather than a percentage of the price.

28. With different pre-tax prices, the optimal ratio is:

$$\frac{t_1}{t_2} = \frac{\varepsilon_2}{\varepsilon_1} \cdot \frac{p_1}{p_2} = \frac{1.1}{0.7} \cdot \frac{80}{50} \approx 1.571 \times 1.6 \approx 2.514$$

So $t_1 \approx 2.514 t_2$. Substituting into the revenue constraint:

$$t_1 Q_1 + t_2 Q_2 = 3,000 \implies 2.514 t_2 (200) + t_2 (300) = 3,000 \implies 802.9 t_2 = 3,000$$

$t_2 \approx \$3.74$	$t_1 \approx \$9.39$
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29. (a) The optimal tax ratio is:

$$\frac{t_1}{t_2} = \frac{\varepsilon_2}{\varepsilon_1} \cdot \frac{p_1}{p_2} = \frac{1.6}{1.3} \cdot \frac{12}{8} \approx 1.231 \times 1.5 \approx 1.846$$

So $t_1 \approx 1.846 t_2$. Substituting into the revenue constraint:

$$1.846 t_2 (600) + t_2 (500) = 2,200 \implies 1,607.7 t_2 = 2,200$$

$t_2 \approx \$1.37$	$t_1 \approx \$2.52$
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- (b) A uniform \$2 tax on both goods raises:

$$\$2(600) + \$2(500) = \$1,200 + \$1,000 = \$2,200$$

The uniform tax raises the same \$2,200 as the optimal tax.

- (c) Although both tax schemes raise the same revenue, the uniform tax generates more deadweight loss than the optimal tax in (a) according to the Ramsey Rule. The optimal tax will tax rideshares more than craft beer since the demand for craft beer is rideshares is more inelastic.

Game Theory

- Two pharmaceutical companies, Apex and Biorex, are each deciding whether to invest heavily in research and development or to keep investment low. The payoff matrix (in millions of dollars of profit) is as follows:

		Biorex	
		Low	High
Apex	Low	A: 8 B: 8	A: 2 B: 12
	High	A: 12 B: 2	A: 4 B: 4

- Does either firm have a dominant strategy? Explain.
 - Identify all Nash equilibria of this game.
- Two rideshare companies, SwiftRide and ZoomCar, are simultaneously choosing which side of the road to adopt for their autonomous vehicle software: drive on the right or drive on the left. If they choose the same side, both benefit from compatibility; if they choose differently, both suffer. The payoff matrix is:

		ZoomCar	
		Left	Right
SwiftRide	Left	SW: 5 Z: 5	SW: -3 Z: -3
	Right	SW: -3 Z: -3	SW: 5 Z: 5

- Are there any dominant strategies in this game?
- Identify all pure strategy Nash equilibria.
- Identify the unique mixed Nash equilibrium

3. A tennis player (the Server) is deciding whether to serve to the opponent's forehand or backhand. The Returner must simultaneously decide which side to anticipate. The probability of the Server winning the point under each combination is given below (the Returner wins the point with the complementary probability):

		Returner	
		Forehand	Backhand
Server	Forehand	S: 0.3 R: 0.7	S: 0.8 R: 0.2
	Backhand	S: 0.9 R: 0.1	S: 0.4 R: 0.6

- Explain why there is no pure strategy Nash equilibrium in this game.
 - Let f be the probability the Server serves to the Forehand. Find the value of f that makes the Returner indifferent between anticipating Forehand and Backhand.
 - Let F be the probability the Returner anticipates the Forehand. Find the value of F that makes the Server indifferent between serving Forehand and Backhand.
 - State the mixed strategy Nash equilibrium of this game.
 - Explain intuitively why a player in a mixed Nash equilibrium is indifferent across their strategies, yet still randomizes.
4. Two streaming platforms, Netflix and HBO Max, are each simultaneously deciding whether to release their flagship show on a Friday or a Sunday. The payoff matrix (in millions of viewers) is:

		HBO Max	
		Friday	Sunday
Netflix	Friday	N: 2 H: 4	N: 3 H: 7
	Sunday	N: 6 H: 8	N: 5 H: 2

- Does either platform have a dominant strategy? Explain.
 - Identify the unique Nash equilibrium and guaranteed outcome of this game.
5. A beachfront town has two competing food truck operators, Sal and Marco, each choosing where to park for the day. Sal can park at the North Beach, Boardwalk, or South Beach while Marco's truck is bigger and can only park at the Boardwalk or South Beach.

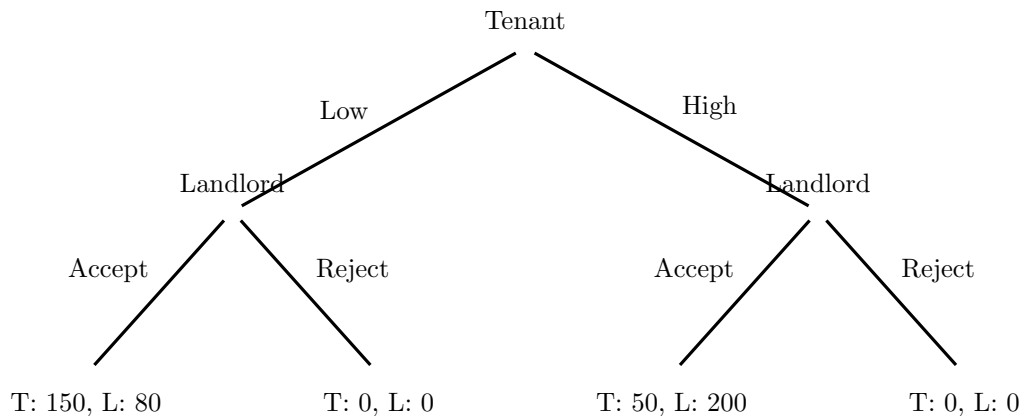
		Marco	
		Boardwalk	South Beach
Sal	North Beach	Sa: 4 M: 6	Sa: 4 M: 3
	Boardwalk	Sa: 2 M: 2	Sa: 6 M: 3
	South Beach	Sa: 5 M: 6	Sa: 1 M: 1

- Does either player have a dominant strategy?
- Identify all Nash equilibria.

6. Two friends, Maya and Noah, are trying to coordinate plans for the evening without being able to communicate. Maya would prefer to go to a concert while Noah would prefer to go to a comedy show, but both prefer spending the evening together over going out alone. The payoff matrix is:

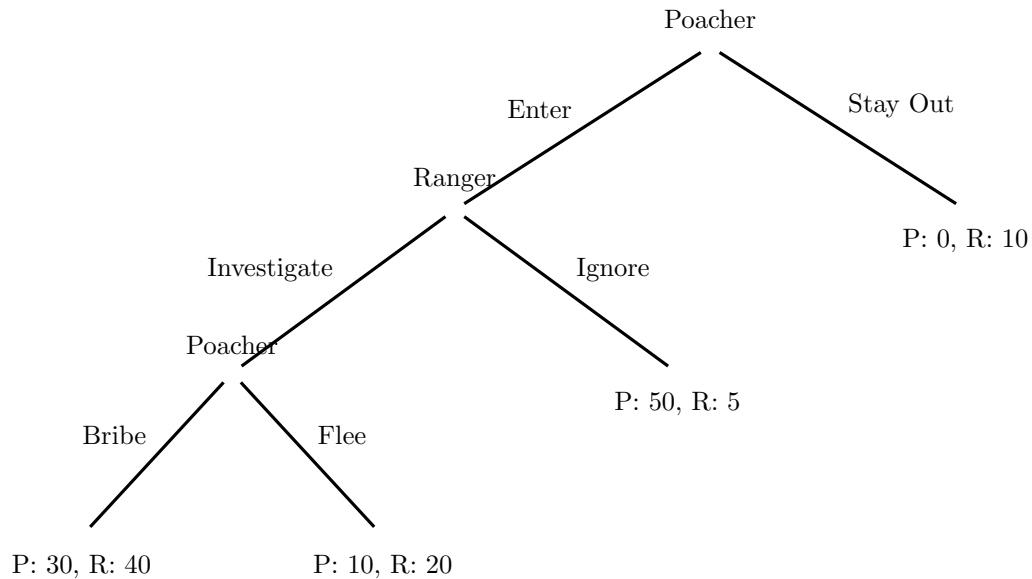
		Noah	
		Concert	Comedy Show
Maya	Concert	M: 6 N: 4	M: 0 N: 0
	Comedy Show	M: 0 N: 0	M: 4 N: 6

- Are there any dominant strategies in this game? Explain.
 - Identify all Nash equilibria.
 - This game is structurally different from the coordination game in Question 2 even though both have two pure Nash equilibria. What is the key difference?
7. A small independent coffee shop, Grounds, is currently the only café in a neighborhood. A national chain, BrewCo, is considering entering the local market. If BrewCo enters, Grounds must decide whether to accommodate BrewCo by maintaining its current prices, or to start a price war. The payoffs (BrewCo, Grounds) are: if BrewCo stays out, (0, 100); if BrewCo enters and Grounds accommodates, (40, 50); if BrewCo enters and Grounds starts a price war, (−20, 10).
- Draw the extensive form (game tree) of this game.
 - Find the subgame perfect Nash equilibrium (SPNE). State the full strategy for each player.
 - Grounds threatens to start a price war if BrewCo enters. Is this threat credible? Why or why not?
 - Suppose Grounds could publicly and irreversibly commit to a price war before BrewCo makes its entry decision (for example, by signing a long-term contract locking in very low prices). How does this change the solution?
8. A landlord and a tenant are negotiating a lease renewal. The tenant moves first, proposing either a low rent increase (\$50/month) or a high rent increase (\$200/month). The landlord then decides whether to Accept or Reject. The payoffs and game tree (Tenant, Landlord) are shown in the extensive form below.

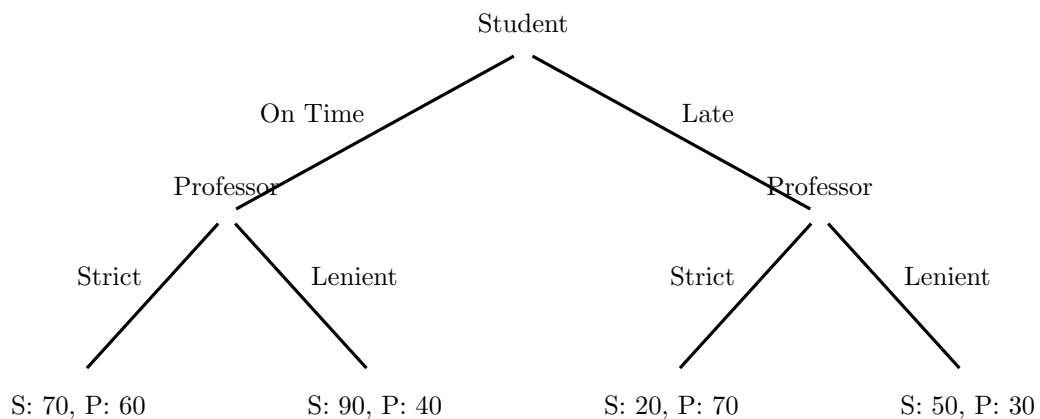


- Use backward induction to find the SPNE. What does the tenant propose, and does the landlord accept?
- Consider the following strategy for the landlord: “Accept only if the offer is High; Reject if the offer is Low.” Is this a Nash equilibrium? Is it a SPNE? Explain the difference.

9. A poacher (Player 1) is deciding whether to enter a protected nature reserve. If the poacher enters, a ranger (Player 2) decides whether to investigate the disturbance or ignore it. If the ranger investigates, the poacher must decide whether to flee or to bribe the ranger. The extensive form of this game with its payoffs is shown below.

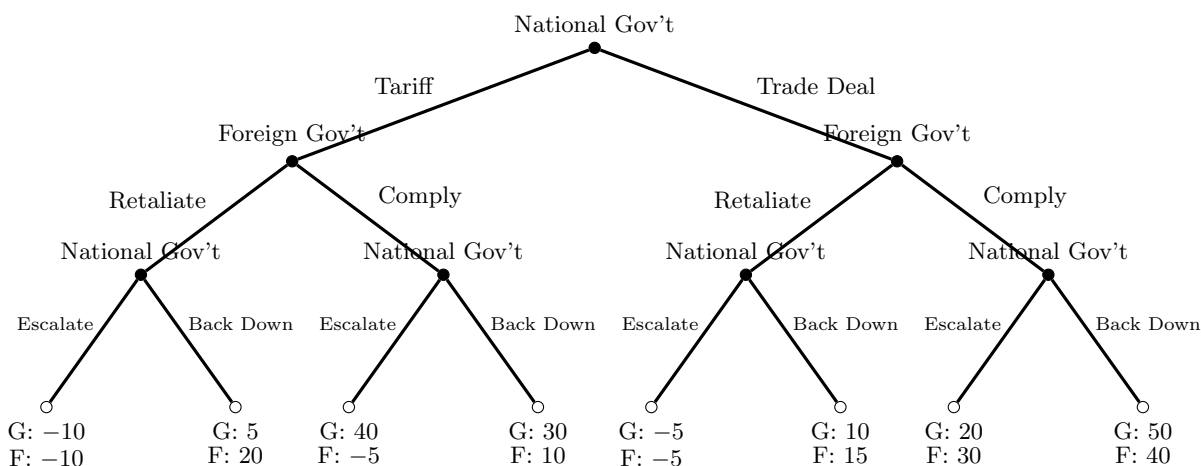


- Find the subgame perfect Nash equilibrium of this game. State the full strategy profile for both players, including the poacher's strategy at every decision node.
 - The ranger threatens to always investigate if the poacher enters. Is this threat credible? Explain.
 - Suppose the ranger could commit to a policy of always investigating, regardless of cost, before the poacher makes his entry decision. How does this change the outcome?
10. A student (Player 1) is deciding whether to submit an essay on time or late. After observing the submission, the professor (Player 2) decides whether to grade it strictly or leniently. The extensive form of this game with its payoffs is shown below.

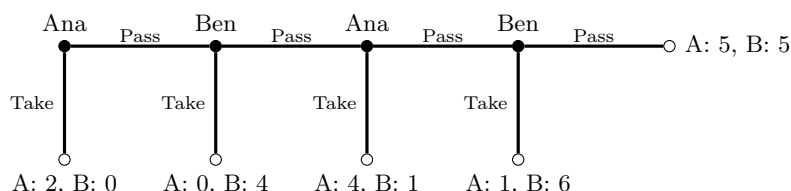


- Find the subgame perfect Nash equilibrium of this game. State the full strategy profile for both players.
- The professor announces on the first day of class that any late submission will be graded leniently. Consider the following strategies: the Student submits On Time, and the Professor grades Strict if On Time and Lenient if Late.
 - Is this strategy profile a Nash equilibrium? Explain why or why not.
 - Is this strategy profile a SPNE? Explain why or why not.
- Given the SPNE, does the student have an incentive to submit on time? What does this suggest about the professor's ability to incentivize timely work through grading policy alone?

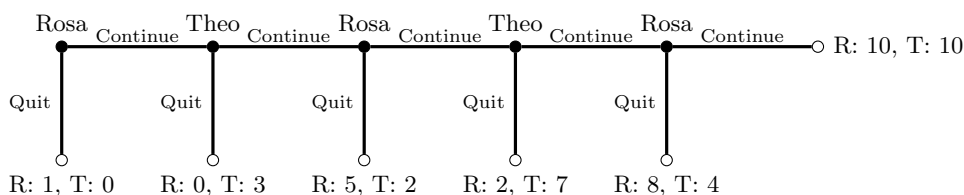
11. The national government (Player 1) is deciding whether to impose a tariff or offer a trade deal to a foreign country (Player 2). After observing the national government's choice, the foreign government decides whether to retaliate or comply. The national government then observes the foreign government's response and decides whether to escalate its position or back down. The extensive form of this game with its payoffs are shown below.



- Use backward induction to find the SPNE.
 - The government threatens to escalate no matter what the foreign country does. Is this threat credible in the SPNE? Explain.
 - Suppose the government could publicly commit to escalating in response to any retaliation before the game begins. How does this change the foreign country's decision, and what does the outcome look like?
12. Two neighbors, Ana and Ben, discover a shared savings bond worth \$2 that was left behind by a previous tenant. Each round, the current holder can either take the bond (ending the game) or pass it to the other neighbor, at which point the bond's value grows. The payoff tree is shown below. Ana moves first.



- Find the SPNE of this game. What happens in equilibrium?
 - If both players passed every turn, both would earn \$5. Why does this outcome not occur when it is the socially optimal outcome?
13. Two software developers, Rosa and Theo, are collaborating on a joint app. At each stage of development, the current developer can either quit the project or continue and hand development to the other. As the project progresses, the total value of the app grows, but the developer who quits always takes a larger share than the one left behind. However, if both continue all the way, they split a large final payoff equally. Rosa moves first. The payoff tree is shown below.



- What is the subgame perfect Nash equilibrium and at which node does the game end?
- What is unusual about this version of the centipede game in comparison to other versions we have talked about in class?

Answers

1. a) Yes, both firms have a dominant strategy. High strictly dominates Low for each firm regardless of what the other does:
 - Apex: if Biorex plays Low, $12 > 8$; if Biorex plays High, $4 > 2$. High is always better.
 - Biorex: if Apex plays Low, $12 > 8$; if Apex plays High, $4 > 2$. High is always better.
- b) Since both firms have a dominant strategy, the unique Nash equilibrium is (High, High) with payoffs (A: 4, B: 4). Note that this is a Prisoner's Dilemma: both firms would be better off at (Low, Low) with payoffs (8, 8), but individual incentives drive them away from (Low, Low).
2. a) No dominant strategies. For any given choice by the other firm, each prefers to match it, so the best response depends entirely on what the other player does.
- b) Two pure strategy Nash equilibria: (Left, Left) with payoffs (5, 5) and (Right, Right) with payoffs (5, 5). In each case neither firm wants to deviate unilaterally, since mismatching gives -3 .
- c) Let $l = P(\text{SwiftRide plays Left})$. Setting ZoomCar's expected utilities equal:

$$\begin{aligned} EU_Z(\text{Left}) &= 5l + (-3)(1-l) = 8l - 3 \\ EU_Z(\text{Right}) &= -3l + 5(1-l) = 5 - 8l \\ 8l - 3 &= 5 - 8l \Rightarrow \boxed{l = \frac{1}{2}} \end{aligned}$$

By symmetry $L = \frac{1}{2}$ for the other ZoomCar as well. Mixed Nash Equilibrium: each firm plays Left with probability $\frac{1}{2}$.

3. a) In any set of pure strategies, one player always has a profitable deviation. If the Server always goes Forehand, the Returner prefers Forehand ($0.7 > 0.1$). But if the Returner always plays Forehand, the Server prefers Backhand ($0.9 > 0.3$). This cycle of best responses means no pure strategy profile is mutually stable.
- b) Let $f = P(\text{Server serves Forehand})$. Setting the Returner's expected utilities equal:

$$\begin{aligned} EU_R(\text{Forehand}) &= 0.7f + 0.1(1-f) = 0.6f + 0.1 \\ EU_R(\text{Backhand}) &= 0.2f + 0.6(1-f) = -0.4f + 0.6 \\ 0.6f + 0.1 &= -0.4f + 0.6 \Rightarrow \boxed{f = \frac{1}{2}} \end{aligned}$$

- c) Let $F = P(\text{Returner anticipates Forehand})$. Setting the Server's expected utilities equal:

$$\begin{aligned} EU_S(\text{Forehand}) &= 0.3F + 0.8(1-F) = 0.8 - 0.5F \\ EU_S(\text{Backhand}) &= 0.9F + 0.4(1-F) = 0.4 + 0.5F \\ 0.8 - 0.5F &= 0.4 + 0.5F \Rightarrow \boxed{F = \frac{2}{5}} \end{aligned}$$

- d) Mixed Nash Equilibrium: Server serves Forehand with probability $\frac{1}{2}$; Returner anticipates Forehand with probability $\frac{2}{5}$.
- e) In a mixed Nash, each player randomizes in a way that makes the other player indifferent. Thus, the other player earns the same expected payoff from any strategy in their support. Since no pure strategy offers a strictly higher payoff, there is no profitable deviation from randomizing. The player still randomizes because if they did not (i.e., put all weight on one action), the opponent would exploit that predictability by shifting to their own best response, unraveling the Nash.
4. a) Yes. Netflix has a dominant strategy of Sunday: regardless of what HBO Max does, Sunday always yields a higher payoff ($6 > 2$ if HBO Max plays Friday; $5 > 3$ if HBO Max plays Sunday). HBO Max has no dominant strategy: if Netflix plays Friday, HBO Max prefers Sunday ($7 > 4$); if Netflix plays Sunday, HBO Max prefers Friday ($8 > 2$). The best response depends on what Netflix does.
- b) Since Netflix always plays Sunday, HBO Max can eliminate Friday from Netflix's strategy set and compare its payoffs in the Sunday row only: Friday gives 8 and Sunday gives 2, so HBO Max plays Friday. The unique Nash equilibrium is (Sunday, Friday) with payoffs (N: 6, H: 8).

5. a) No dominant strategy for either player. For Sal: no single row dominates another across both of Marco's strategies. For Marco: Boardwalk gives $6 > 3$ when Sal plays North Beach or South Beach, but $2 < 3$ when Sal plays Boardwalk, so neither column dominates.
- b) Checking each cell for profitable deviations:

- (North Beach, Boardwalk): Sal earns 4; deviating to South Beach gives $5 > 4$. Not Nash.
- (North Beach, South Beach): Sal earns 4; deviating to Boardwalk gives $6 > 4$. Not Nash.
- (Boardwalk, Boardwalk): Sal earns 2; deviating to South Beach gives $5 > 2$. Not Nash.
- (Boardwalk, South Beach): Sal earns 6; deviating to North Beach gives $4 < 6$, South Beach gives $1 < 6$. No deviation. Marco earns 3; deviating to Boardwalk gives $2 < 3$. No deviation. Nash.
- (South Beach, Boardwalk): Sal earns 5; deviating to North Beach gives $4 < 5$, Boardwalk gives $2 < 5$. No deviation. Marco earns 6; deviating to South Beach gives $1 < 6$. No deviation. Nash.
- (South Beach, South Beach): Sal earns 1; deviating to Boardwalk gives $6 > 1$. Not Nash.

Nash equilibria: (Boardwalk, South Beach) with payoffs (Sa: 6, M: 3) and (South Beach, Boardwalk) with payoffs (Sa: 5, M: 6).

6. a) No dominant strategies. Maya prefers to match Noah's choice, and vice versa, so each player's best response depends on what the other does.
- b) Two pure Nash equilibria: (Concert, Concert) with payoffs (M: 6, N: 4) and (Comedy Show, Comedy Show) with payoffs (M: 4, N: 6).

For the mixed Nash, let $p = P(\text{Maya plays Concert})$:

$$\begin{aligned} EU_N(\text{Concert}) &= 4p \\ EU_N(\text{Comedy Show}) &= 6(1 - p) \\ 4p &= 6 - 6p \Rightarrow \boxed{p = \frac{3}{5}} \end{aligned}$$

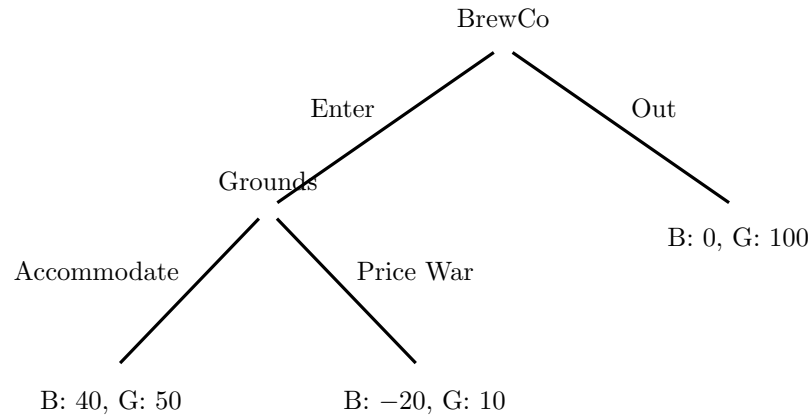
Let $q = P(\text{Noah plays Concert})$:

$$\begin{aligned} EU_M(\text{Concert}) &= 6q \\ EU_M(\text{Comedy Show}) &= 4(1 - q) \\ 6q &= 4 - 4q \Rightarrow \boxed{q = \frac{2}{5}} \end{aligned}$$

Mixed Nash Equilibrium: Maya plays Concert with probability $\frac{3}{5}$; Noah plays Concert with probability $\frac{2}{5}$.

- c) In Question 2, both players are indifferent between the two equilibria since the payoffs are symmetric, so any coordination is as good as any other. Here, Maya strictly prefers (Concert, Concert) and Noah strictly prefers (Comedy Show, Comedy Show), so while both want to coordinate, they disagree on which equilibrium to reach.

7. a) The game is represented using the tree below.



- b) Working backwards: if BrewCo enters, Grounds chooses between Accommodate (payoff 50) and Price War (payoff 10) and prefers to Accommodate. Knowing this, BrewCo compares Enter (payoff 40) to Out (payoff 0) and chooses to Enter.
 SPNE strategy profile: BrewCo Enters; Grounds Accommodates.
- c) No, the threat is not credible. If BrewCo enters, Grounds earns 10 from a price war versus 50 from accommodating. Starting a price war is not a best response in that subgame, so Grounds would never follow through. BrewCo knows this and enters anyway.
- d) If Grounds commits irreversibly to a price war, the game changes: BrewCo now anticipates a payoff of -20 upon entering rather than 40. Since $0 > -20$, BrewCo's best response is to stay Out. Grounds earns 100 instead of 50. The commitment works precisely because it removes Grounds' ability to back down. The threat that was previously empty becomes credible, and BrewCo is deterred from entering.
8. a) Working backwards: the Landlord accepts both offers since $80 > 0$ and $200 > 0$. The Tenant therefore chooses between Low (payoff 150) and High (payoff 50) and proposes Low.
 SPNE strategy profile: Tenant proposes Low; Landlord accepts any offer.
- b) Nash? If the Tenant deviates to Low, the Landlord rejects and the Tenant gets $0 < 50$. No profitable deviation for the Tenant. The Landlord's strategy is a best response on the reached (High) branch since $200 > 0$. If the Landlord deviates on the reached branch and Rejects, the Landlord gets $0 < 200$. No profitable one-shot deviation for either player. Thus this is a Nash equilibrium.
 SPNE? No. On the off-path Low branch, the Landlord plays Reject (payoff 0) instead of Accept (payoff 80). This is not a best response in that subgame, so the strategy is not sequentially rational. The threat to reject a Low offer is an empty threat, and the profile is not a SPNE.
9. a) Working backwards: at the Poacher's second decision node, Bribe (30) $>$ Flee (10), so the Poacher bribes. Given this, the Ranger compares Investigate (payoff 40) versus Ignore (payoff 5) and chooses to Investigate. At the entry node, the Poacher compares Enter (payoff 30) versus Stay Out (payoff 0) and chooses to Enter.
 SPNE strategy profile: Poacher Enters and Bribes if Investigated; Ranger Investigates if Poacher Enters. Outcome: (P: 30, R: 40).
- b) Yes, the threat is credible. If the Poacher enters, the Ranger earns 40 by investigating versus 5 by ignoring and so investigating is a strict best response in that subgame. There is no sequential irrationality here.
- c) The outcome does not change. The Poacher's payoffs are unchanged: Enter still leads to investigation and a bribe, yielding 30, which exceeds Stay Out (0). The commitment has no effect because the Ranger's threat was already credible.

10. a) Working backwards: the Professor's best response is Strict regardless of when the essay is submitted ($60 > 40$ if On Time; $70 > 30$ if Late). The Student compares On Time + Strict (70) to Late + Strict (20) and chooses On Time.
 SPNE strategy profile: Student submits On Time; Professor grades Strict after both On Time and Late submissions.
- b) i) Nash? The Student earns 70 on the equilibrium path. Deviating to Late yields 50 (Professor plays Lenient off-path), which is less than 70 so no profitable deviation. The Professor's strategy is a best response on the reached On Time branch ($60 > 40$). No profitable one-shot deviation for either player and so this is a Nash equilibrium.
 ii) SPNE? No. On the off-path Late branch, the Professor plays Lenient (30) rather than Strict (70). This is not a best response in that subgame, so the strategy is not sequentially rational. The promise to grade leniently for late work is an empty threat, and the profile is not a SPNE.
- c) In the SPNE the Professor grades Strict regardless, so the Student earns 70 submitting On Time versus 20 submitting Late. The Student will then submit on time. However, this is not because the grading policy credibly incentivizes punctuality; the Professor grades strictly no matter what. The threat of strict grading for late work cannot function as a disciplinary tool because it is already being carried out unconditionally.
11. a) Working backwards at each of the four Gov't nodes:
- Tariff/Retaliates: Back Down (5) > Escalate (-10)
 - Tariff/Comply: Escalate (40) > Back Down (30)
 - Trade Deal/Retaliates: Back Down (10) > Escalate (-5)
 - Trade Deal/Comply: Back Down (50) > Escalate (20)
- Foreign Gov't at Tariff branch: Retaliate $\Rightarrow$ Gov't Backs Down $\Rightarrow$ F: 20; Comply $\Rightarrow$ Gov't Escalates $\Rightarrow$ F: -5. Foreign Retaliates.
 Foreign Gov't at Trade Deal branch: Retaliate $\Rightarrow$ Gov't Backs Down $\Rightarrow$ F: 15; Comply $\Rightarrow$ Gov't Backs Down $\Rightarrow$ F: 40. Foreign Complies.
 Gov't at root: Tariff $\Rightarrow$ Foreign Retaliates $\Rightarrow$ Back Down $\Rightarrow$ G: 5; Trade Deal $\Rightarrow$ Foreign Complies $\Rightarrow$ Back Down $\Rightarrow$ G: 50. Gov't offers Trade Deal.
 SPNE strategy profile: National gov't offers Trade Deal; Foreign Complies; National gov't Backs Down at every node if reached. Outcome: (G: 50, F: 40).
- b) Not credible at the Tariff/Retaliates node, where Back Down (5) strictly dominates Escalate (-10). The government would never escalate after a tariff provokes retaliation. The only node where escalation is a best response is Tariff/Comply, but that node will never be reached.
- c) If the government commits to escalating after any retaliation, the Foreign Gov't at the Tariff branch now compares Retaliate $\Rightarrow$ Escalate $\Rightarrow$ F: -10 versus Comply $\Rightarrow$ Escalate $\Rightarrow$ F: -5, and chooses Comply. The Gov't then earns 40 (Tariff/Comply/Escalate). Since Trade Deal still yields 50, the government continues to prefer the Trade Deal. The commitment changes Foreign's behavior on the Tariff branch but does not change the outcome.
12. a) Working backwards:
- Ben at node 4: Take (B: 6) > Pass (B: 5) $\Rightarrow$ Take
 - Ana at node 3: Take (A: 4) > Pass $\Rightarrow$ Ben Takes (A: 1) $\Rightarrow$ Take
 - Ben at node 2: Take (B: 4) > Pass $\Rightarrow$ Ana Takes (B: 1) $\Rightarrow$ Take
 - Ana at node 1: Take (A: 2) > Pass $\Rightarrow$ Ben Takes (A: 0) $\Rightarrow$ Take
- SPNE: Ana takes immediately at node 1. Outcome: (A: 2, B: 0).
- b) Passing all the way yields (5, 5), which makes both players better off. However, backward induction unravels cooperation from the end: Ben would take at node 4 rather than pass for an equal split, so Ana takes at node 3 rather than hand Ben the opportunity, and so on back to the start. Each player's individually rational response to what comes next destroys the cooperative outcome.

13. a) Working backwards:

- Rosa at R3: Continue (R: 10) > Quit (R: 8) $\Rightarrow$ Continue
- Theo at T2: Continue (T: 10) > Quit (T: 7) $\Rightarrow$ Continue
- Rosa at R2: Continue (R: 10) > Quit (R: 5) $\Rightarrow$ Continue
- Theo at T1: Continue (T: 10) > Quit (T: 3) $\Rightarrow$ Continue
- Rosa at R1: Continue (R: 10) > Quit (R: 1) $\Rightarrow$ Continue

SPNE: Both players continue at every node. Outcome: (R: 10, T: 10).

- b) Unlike the standard centipede game, backward induction does not unravel cooperation here and the game reaches the final payoff node in equilibrium. This occurs because the terminal payoff (10, 10) is large enough to dominate the outside option at every single node, so no player ever has an incentive to quit. The standard centipede unravels because each player's take payoff eventually exceeds the continuation value; here it never does.

Quiz #1

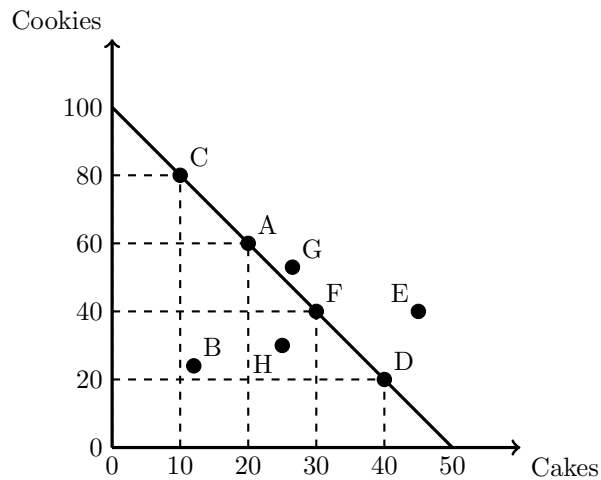
Intermediate Microeconomic Theory

Instructor: Colin Adams

Questions

1. You have _____ quiz attempts available, and only your highest score will count.
 - A) 1
 - B) 2
 - C) 3
 - D) 4
 - E) 5
2. The midterm will occur on which day?
 - A) May 27th
 - B) May 29th
 - C) June 1st
 - D) June 5th
 - E) None of the Above
3. The final will occur on which day?
 - A) June 12th
 - B) June 15th
 - C) June 17th
 - D) June 19th
 - E) None of the Above
4. Which of the following best describes the composite good?
 - A) A single good representing all other goods in the economy besides the one being explicitly analyzed
 - B) A good produced jointly with another good in the same production process
 - C) A single good created by combining multiple intermediate inputs into one final product
 - D) A good for which demand increases when consumer income increases, holding other factors constant
 - E) None of the above describe the composite good

Bob can buy either cakes for \$12 or a box of cookies for \$6. Use the budget set below to answer questions 5-9.



5. What is Bob's income?
 - A) \$0
 - B) \$60
 - C) \$300
 - D) \$1,200
 - E) None of the Above
6. What is the slope of the budget line?
 - A) -2
 - B) $\frac{1}{2}$
 - C) 1
 - D) 2
 - E) None of the Above
7. Bob decided to buy 42 cookies. Which of the following is the maximum number of cakes that he can buy?
 - A) 0
 - B) 21
 - C) 50
 - D) 58
 - E) None of the Above
8. How much does a bundle of 25 cakes and 40 cookies cost?
 - A) \$60
 - B) \$540
 - C) \$600
 - D) \$630
 - E) None of the Above
9. Is the bundle of 31 cakes and 39 cookies attainable for Bob?
 - A) Yes
 - B) No
 - C) We cannot determine if the bundle is attainable or not
 - D) None of the Above

Alice has a weekly income of \$1,200. She may buy cereal at \$10 a box for the first 8 boxes, then every additional box is \$5. Use this information to answer question 10-12.

10. How many boxes of cereal may Alice buy at a maximum?
 - A) 120
 - B) 232
 - C) 240
 - D) 300
 - E) None of the Above
11. What is the maximum quantity of the composite good that Alice can purchase if she buys 150 boxes of cereal?
 - A) 410
 - B) 450
 - C) 600
 - D) 1,200
 - E) None of the Above
12. Which of the following bundles is a candidate for the optimal bundle?
 - A) 100 boxes of cereal and 659 of the composite good
 - B) 140 boxes of cereal and 475 of the composite good
 - C) 220 boxes of cereal and 210 of the composite good
 - D) 230 boxes of cereal and 5 of the composite good
 - E) None of the Above

Quiz #2

Intermediate Microeconomic Theory

Instructor: Colin Adams

Questions

1. Suppose I prefer earbuds to speakers and headphones to earbuds. Which of the following must be true if my preferences are transitive?
 - A) I prefer headphones to speakers
 - B) I prefer speakers to headphones
 - C) I am indifferent between headphones and speakers
 - D) My preferences are complete
 - E) None of the above
2. Joe's preferences are complete. Which of the following cannot be correct about his preferences towards sodas.
 - A) Joe prefers Coke to Pepsi
 - B) Joe prefers Pepsi to Coke
 - C) Joe prefers Dr. Pepper to Coke and Pepsi
 - D) Joe cannot rank Dr. Pepper against Coke or Pepsi
 - E) Joe is indifferent between Dr. Pepper, Coke, and Pepsi
3. Sarah's preferences are monotone. Which of the following is consistent with her preferences?
 - A) She is indifferent between a bundle with more of both goods and one with less of both
 - B) She prefers a bundle with less of both apples and oranges to one with more of both
 - C) She prefers a bundle with more apples and the same number of oranges to the original bundle
 - D) She prefers a bundle with fewer apples as long as she has enough oranges
 - E) She may prefer a bundle with less of both goods on some days and more on others
4. Which of the following implies there exists a utility function representing the preference?
 - A) The preference is complete
 - B) The preference is transitive
 - C) The preference is rational
 - D) The preference is monotone
 - E) None of the Above
5. Zach prefers more money to less, until he has more than \$100, at which point he prefers less money. Which of the following assumptions of preferences does Zach violate?
 - A) Completeness
 - B) Transitivity
 - C) Rationality
 - D) Monotonicity
 - E) None of the Above

For questions 6-10, consider Dolly who has the following preferences across hours spent making music (M) and acting (A). Dolly's utility function is the following: $U(M, A) = 6M^{\frac{1}{3}} + 2A^{\frac{1}{2}}$.

6. Which of the following is Dolly's marginal utility of making music?
 - A) $6M^{\frac{1}{3}}$
 - B) $2M^{\frac{1}{3}}$
 - C) $2M^{-\frac{2}{3}} + 2A^{\frac{1}{2}}$
 - D) $6M^{\frac{1}{3}} + A^{-\frac{1}{2}}$
 - E) None of the Above
7. Which of the following is Dolly's marginal utility of acting?
 - A) 0
 - B) $A^{-\frac{1}{2}}$
 - C) $2A^{\frac{1}{2}}$
 - D) $2M^{-\frac{2}{3}} + A^{-\frac{1}{2}}$
 - E) None of the Above
8. Which of the following is true of Dolly's preferences?
 - A) They exhibit diminishing marginal return in making music
 - B) They exhibit diminishing marginal return in acting
 - C) They exhibit diminishing marginal return in making music and acting
 - D) None of the Above
9. Dolly currently spends 27 hours making music and 25 hours acting per week. Which of the following options would she be indifferent between?
 - A) 8 hours making music and 64 hours acting
 - B) 10 hours making music and 40 hours acting
 - C) 20 hours making music and 20 hours acting
 - D) 30 hours making music and 30 hours acting
 - E) None of the Above
10. Which of the following represents Dolly's marginal rate of substitution?

A) $-\frac{4M^{-\frac{5}{3}}}{6A^{-\frac{3}{2}}}$ B) $-\frac{6M^{\frac{1}{3}}}{2A^{\frac{1}{2}}}$ C) $-\frac{2M^{-\frac{2}{3}}}{2A^{\frac{1}{2}}}$	D) $-\frac{6M^{\frac{1}{3}}}{A^{-\frac{1}{2}}}$ E) $-\frac{2M^{-\frac{2}{3}}}{A^{-\frac{1}{2}}}$ F) Neither A, B, C, D, or E are her MRS
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11. Which of the following is not a property of indifference curves?
 - A) Indifference curves can intersect
 - B) Every bundle is on some indifference curve
 - C) Indifference curves near the origin have lower utility than those away from the origin
 - D) All of the above are properties of indifference curves

Quiz #3

Intermediate Microeconomic Theory

Instructor: Colin Adams

Questions

1. Which of the following is only true of the optimal bundle?
 - A) The indifference curve is downward sloped at the optimal bundle
 - B) The optimal bundle is on the budget line
 - C) The marginal rate of substitution is maximized
 - D) It is the only optimal bundle
 - E) None of the Above
2. Which of the following best describes a corner solution?
 - A) A solution where the consumer spends equal amounts of income on all available goods
 - B) A solution where the marginal rate of substitution equals the price ratio
 - C) A solution where the consumer's indifference curve is tangent to the budget line
 - D) A solution where the marginal utility of each good consumed is equal across all goods
 - E) None of the Above
3. Which of the following are the most likely to be perfect substitutes?
 - A) Gasoline with identical octane ratings purchased at different stations
 - B) A left shoe and a right shoe
 - C) Rice and pasta for a consumer who loves pasta
 - D) A violin and a tuba for a musician
 - E) Netflix and a textbook for a student during finals week
4. Which of the following best illustrates the difference between a normal good and an inferior good?
 - A) As the price of a good falls, consumption of a normal good rises while consumption of an inferior good falls
 - B) A good is normal if consumers prefer it regardless of income, and inferior if consumers only purchase it when wealthier substitutes are unavailable
 - C) As income rises, a consumer buys more chicken but switches away from canned tuna, indicating chicken breast is a normal good and canned tuna is an inferior good
 - D) As income rises, demand increases for both types of goods, but the increase is smaller for inferior goods
 - E) All of the Above are true
5. A consumer buys a large quantity of ramen noodles. Assume ramen noodles to be an inferior good. When the price of ramen falls, the consumer ultimately buys less ramen. Which of the following best explains this outcome?
 - A) This outcome is impossible since the law of demand guarantees consumption rises
 - B) The income effect and substitution effect work in the same direction
 - C) The substitution effect outweighs the income effect
 - D) The income effect outweighs the substitution effect

James enjoys sandwiches (S) and tea (T). James has \$56. Sandwiches cost \$2 and tea \$3 each. James has the following utility function. Use this information to answer questions 6-8.

$$U(S, T) = \sqrt{S} + 3\sqrt{T}$$

6. What is James's marginal utility of tea?

- A) $\frac{1}{2\sqrt{T}}$
- B) $\frac{3}{2\sqrt{T}}$
- C) $\sqrt{T}$
- D) $2\sqrt{T}$
- E) None of the Above

7. Which of the following is James's optimal bundle?

- A) 4 sandwiches and 16 tea
- B) 9 sandwiches and 16 tea
- C) 16 sandwiches and 4 tea
- D) 16 sandwiches and 9 tea
- E) None of the Above

8. Suppose James already chose to consume nine sandwiches and four teas. James can now choose to consume more of either, but not both good. Which of the following is true?

- A) James should consume more sandwiches
- B) James should consume more teas
- C) James should not consume more of either good
- D) We cannot determine which good James should consume more of

Jan has \$56 to spend on bagels (B) and coffee (C) for a study session and has the utility function below. Bagels cost \$2 each and coffees cost \$6 each. Use this information to answer questions 9 and 10.

$$U(B, C) = B^{\frac{1}{3}} + 3C^{\frac{1}{3}}$$

9. Which of the following is Jan's marginal rate of substitution between bagels and coffee?

- | | |
|--|--|
| <ul style="list-style-type: none"> A) $\frac{1}{3} \left(\frac{C}{B} \right)^{\frac{2}{3}}$ B) $\left(\frac{C}{B} \right)^{\frac{2}{3}}$ | <ul style="list-style-type: none"> C) $2 \left(\frac{C}{B} \right)^{\frac{1}{3}}$ D) $3 \left(\frac{C}{B} \right)^{\frac{1}{3}}$ |
|--|--|

10. Which of the following is Jan's optimal bundle?

- A) 4 bagels and 4 coffee
- B) 7 bagels and 7 coffee
- C) 14 bagels and 4 coffee
- D) 25 bagels and 1 coffee
- E) None of the Above

Quiz #4

Intermediate Microeconomic Theory

Instructor: Colin Adams

Questions

1. Which of the following is true in the short-run?
 - A) At least one cost or input is fixed
 - B) All costs or inputs are fixed
 - C) All costs or inputs are variable
 - D) Firms cannot change their output
 - E) None of the Above
2. Economists assume the singular goal of all firms to be which of the following?
 - A) Minimize cost
 - B) Maximize revenue
 - C) Maximize market share
 - D) Maximize profit
 - E) None of the Above
3. We refer to which of the following as the rate at which a firm is willing to trade labor for capital, keeping quantity constant?
 - A) Isoquant
 - B) Marginal Rate of Technical Substitution
 - C) Marginal Rate of Substitution
 - D) Marginal Cost
 - E) None of the Above

Costco is making golf balls. They have a land for a factory which costs \$1,000 per acre and they have 5 acres for their golf ball factory. They cannot change the amount of land they have for this factory. Costco also uses labor in the production of golf balls. Labor costs them \$20 per hour. They have the production function below. Use this information to answer questions 4-7.

$$Q = 12L^{\frac{1}{4}}$$

4. What is Costco's fixed cost for producing golf balls?
 - A) \$0
 - B) \$100
 - C) \$5,000
 - D) \$6,000
 - E) \$20,000

5. What is Costco's marginal cost of producing golf balls?

- A) $\frac{20}{Q}$
- B) $\frac{5Q^3}{1,296}$
- C) $\frac{5Q}{1,296}$
- D) $\frac{80Q^3}{12}$
- E) None of the Above

6. Suppose Costco chooses to produce 24 golf balls. How much labor should they choose to use to produce 24 golf balls?

- A) 2
- B) 4
- C) 8
- D) 16
- E) None of the Above

7. Suppose Costco chooses to produce 24 golf balls. What is Costco's additional production of adding one more unit of labor (worker/hour)?

- A) 0
- B) $\frac{3}{16}$
- C) $\frac{1}{4}$
- D) $\frac{3}{4}$
- E) None of the Above

Toyota is making keys for their cars. They may choose between building more factories, denoted as K , and hiring more labor, denoted as L . Toyota has the production function given below. Use this information to answer questions 8-10.

$$Q = 50K^{\frac{1}{2}} + 10L$$

8. Suppose Toyota decides to make 200 keys and build 9 factories. How much labor should Toyota hire?

- A) 2
- B) 9
- C) 15
- D) 20
- E) None of the Above

9. What is Toyota's marginal product of labor?

- A) $\frac{1}{4}$
- B) $\frac{25}{\sqrt{K}}$
- C) $10L$
- D) $\frac{2\sqrt{K}}{5}$
- E) None of the Above

10. Which of the following represents the rate at which Toyota would trade labor for capital?

- A) $\frac{2\sqrt{K}}{5}$
- B) $\frac{25}{\sqrt{K}}$
- C) $2\sqrt{K}$
- D) 10
- E) None of the Above

Quiz #5

Intermediate Microeconomic Theory

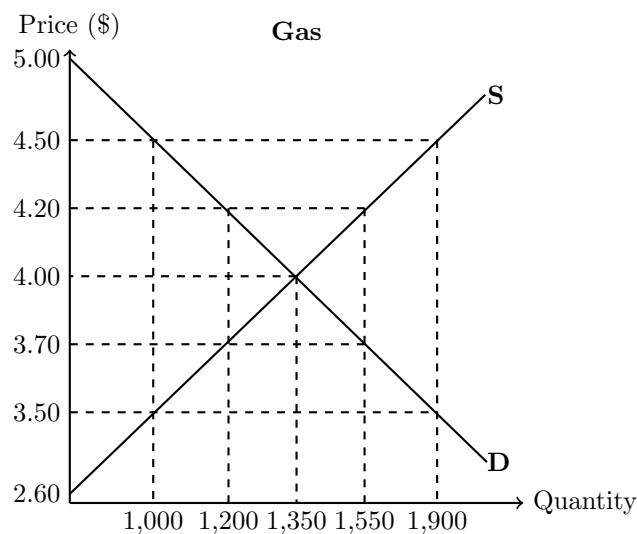
Instructor: Colin Adams

Questions

1. Which of the following is not true in the long-run?
 - A) All costs are variable
 - B) Firms engaged in perfect competition have zero profit
 - C) Perfectly competitive markets have no barriers to entry
 - D) Perfectly competitive markets have few buyers and sellers
 - E) None of the above
2. Which of the following best describes an ad valorem tax?
 - A) A flat fee charged per unit of a good, regardless of its price
 - B) A levy assessed as a percentage of the assessed worth of the item being taxed
 - C) A tax imposed only on imported goods at the point of entry
 - D) A one-time levy on the transfer of property between a buyer and seller
 - E) None of the above
3. Which of the following best describes the difference between statutory and actual incidence?
 - A) Statutory incidence applies to firms; actual incidence applies to households
 - B) Statutory incidence is the short-run effect; actual incidence is the long-run effect
 - C) Statutory incidence measures deadweight loss; actual incidence measures revenue collected
 - D) Statutory incidence is the pre-tax price; actual incidence is the post-tax price
 - E) None of the above
4. How do we know which side of a market receives the greater actual incidence?
 - A) The more elastic side bears more of the burden
 - B) Whichever side the tax is legally imposed on bears more of the burden
 - C) The less elastic side bears more of the burden
 - D) Both sides always share the burden equally regardless of market conditions
 - E) None of the above
5. Which of the following refers to the total benefit to sellers from participating in a market?
 - A) Producer surplus
 - B) Consumer surplus
 - C) Total surplus
 - D) Economic profit
 - E) Deadweight loss

6. Higher education generates positive externalities. Which of the following policies would most likely move this market closer to allocative efficiency?
- A per-credit tuition tax that raises revenue for the government
 - A cap on total university enrollment set below current levels
 - A tax on university profits that reduces the number of institutions
 - Free tuition for low-income students
 - Limiting degree programs to fields with current labor shortages only
7. Which of the following is not a possible fix to a market with a negative externality?
- Pigouvian tax
 - Production quota
 - Emissions tax
 - Emissions quota
 - All of the above are possible fixes

Use the following graph representing the market for gas to answer questions 8-10.



8. What quantity is this market currently operating at?
- 1,000
 - 1,200
 - 1,350
 - 1,550
 - 1,900
9. Suppose gas creates a negative externality. The government determines the socially optimal quantity to be 1,000 gallons of gas. What should be the Pigouvian tax on gas to reach the socially optimal quantity?
- \$0.50
 - \$1.00
 - \$2.40
 - \$3.50
 - There is no Pigouvian tax that would achieve the socially optimal quantity
10. Which of the following would be an adverse effect of a Pigouvian tax, such as the one in question 9?
- It would raise tax revenue
 - It would increase the quantity of gas
 - It would come with high monitoring costs
 - It would be costly to enforce
 - None of the above are adverse effects of a Pigouvian tax

Quiz #6

Intermediate Microeconomic Theory

Instructor: Colin Adams

Questions

1. Which of the following best explains why an excise tax creates deadweight loss?
 - A) The tax raises prices for all consumers, including those who continue to purchase the good
 - B) The tax causes some mutually beneficial transactions to no longer occur
 - C) The tax transfers consumer surplus to the government
 - D) The tax reduces producer profits below zero
 - E) None of the above
2. The Ramsey rule is designed to achieve which of the following objectives?
 - A) Raise a target amount of revenue while minimizing deadweight loss
 - B) Tax all goods at the same rate to ensure fairness
 - C) Eliminate deadweight loss entirely through optimal tax design
 - D) Maximize government revenue regardless of efficiency costs
 - E) None of the above
3. Which of the following is the most efficient tax system?
 - A) Taxes on only inelastic goods
 - B) Taxes on only elastic goods
 - C) Taxes on all goods
 - D) Taxes on all goods but more so on inelastic goods
 - E) Lump sum taxes charged to an individual
4. Which of the following correctly identifies a limitation of the Ramsey rule related to how markets interact?
 - A) The rule assumes perfectly competitive markets, which rarely exist in practice
 - B) The rule ignores spillover effects across markets
 - C) The rule requires the government to observe consumer utility functions directly
 - D) The rule only applies when all goods have the same pre-tax price
 - E) None of the above
5. Suppose the government must raise a fixed amount of revenue by taxing two goods. Good 1 has a price elasticity of demand of $\varepsilon_1 = 0.4$ and Good 2 has $\varepsilon_2 = 1.2$. According to the Ramsey rule, how much should the first good be taxed in relation to the second good?
 - A) $t_1 = 1/3 t_2$
 - B) $t_1 = 3 t_2$
 - C) $t_1 = 1/2 t_2$
 - D) $t_1 = 2 t_2$
 - E) None of the above

6. A government taxes electricity and airline tickets. Electricity has $\varepsilon = 0.3$ and airline tickets have $\varepsilon = 0.9$. Under the Ramsey rule, which of the following is true?
- A) Airline tickets should be taxed three times as heavily as electricity
 - B) Electricity and airline tickets should be taxed at a 2-to-1 ratio
 - C) Both goods should be taxed at the same rate since both are commonly consumed
 - D) Airline tickets should not be taxed because they support economic activity
 - E) None of the above
7. The government needs to raise \$1,400 in tax revenue and can tax gasoline (good 1) and train tickets (good 2). Gasoline has an elasticity of demand ε_1 equal to 0.25 and train tickets has that of $\varepsilon_2 = 0.75$. Currently 400 gallons of gasoline and 200 train tickets are being transacted. What are the optimal tax rates to raise \$1,400 in tax revenue if that is our only goal?
- A) Tax gasoline \$3.50 and don't tax train tickets
 - B) Tax gasoline \$1 and train tickets \$3
 - C) Tax gasoline \$2 and train tickets \$2
 - D) Tax gasoline \$0.75 and train tickets \$0.25
 - E) None of the above represent the best tax in this situation.

Quiz #7

Intermediate Microeconomic Theory

Instructor: Colin Adams

Questions

1. Which of the following best describes the double dividend of Pigouvian taxes?
 - A) Pigouvian taxes lower prices and increase consumer surplus
 - B) Pigouvian taxes restore allocative efficiency by reducing output and simultaneously generate tax revenue
 - C) Pigouvian taxes eliminate deadweight loss and increase producer surplus
 - D) Pigouvian taxes reduce both the quantity produced and the price consumers pay
 - E) Pigouvian taxes generate revenue and encourage firms to produce more than the socially optimal quantity
2. Which of the following best distinguishes an emissions tax from a Pigouvian tax?
 - A) An emissions tax targets output directly while a Pigouvian tax targets the pollutant
 - B) An emissions tax is based on the quantity of pollutant emitted rather than the quantity of output produced
 - C) An emissions tax eliminates deadweight loss while a Pigouvian tax does not
 - D) An emissions tax is paid by consumers while a Pigouvian tax is paid by producers
 - E) An emissions tax raises no government revenue while a Pigouvian tax does
3. Which of the following is a potential fix to restore allocative efficiency in a market with a positive externality?
 - A) Production Quota
 - B) Mandate
 - C) Pigouvian tax
 - D) Emissions tax
 - E) Emissions quota
4. Which of the following is not a cause of monopoly formation?
 - A) Economies of scale driven by declining average fixed costs
 - B) Government-issued patents granting exclusive rights to sell a product
 - C) A firm gaining control over an essential resource
 - D) Licensing requirements that restrict entry into a market
 - E) Decreasing returns to scale
5. Relative to a perfectly competitive market, a monopoly leads to which of the following?
 - A) Lower prices
 - B) Lower quantity
 - C) Higher efficiency
 - D) Less producer surplus
 - E) More consumer surplus

6. Which of the following best explains why natural monopolies are considered the socially optimal market structure?
- A) They eliminate all deadweight loss by producing at the perfectly competitive quantity
 - B) Their high fixed costs are incurred only once, and economies of scale allow average costs to fall
 - C) They are the only market structure in which firms earn zero economic profit in the long run
 - D) They prevent any form of price discrimination, which maximizes consumer surplus
 - E) Their barriers to entry guarantee that prices will be set equal to marginal cost
7. Which of the following is a necessary condition for a firm to successfully price discriminate?
- A) The firm must operate in a perfectly competitive market
 - B) The firm must produce a good with no external costs or benefits
 - C) Arbitrage must be easy so that consumers can resell the good freely
 - D) The firm must be a price searcher
 - E) The firm must charge the same price to all consumer groups
8. Which of the following best explains why there is no deadweight loss under perfect price discrimination?
- A) The firm sets price equal to average total cost
 - B) The firm charges every consumer the same price
 - C) Each consumer is charged exactly their willingness to pay
 - D) Consumer surplus is maximized
 - E) The firm restricts output to the point where marginal revenue equals average total cost
9. A software company offers three subscription tiers: a basic plan for \$5 per month, a standard plan for \$12 per month, and a premium plan for \$20 per month. Customers choose the plan that best fits their needs, and the firm does not know in advance which type of user each customer is. Which type of price discrimination does this best represent?
- A) Perfect price discrimination
 - B) 2nd degree price discrimination
 - C) 3rd degree price discrimination
 - D) None of the above
10. A grocery store sells a 1-pound bag of coffee for \$8 and a 5-pound bag of the same coffee for \$30. Which type of price discrimination does this best represent?
- A) Perfect price discrimination
 - B) 2nd degree price discrimination
 - C) 3rd degree price discrimination
 - D) None of the above

Quiz #8

Intermediate Microeconomic Theory

Instructor: Colin Adams

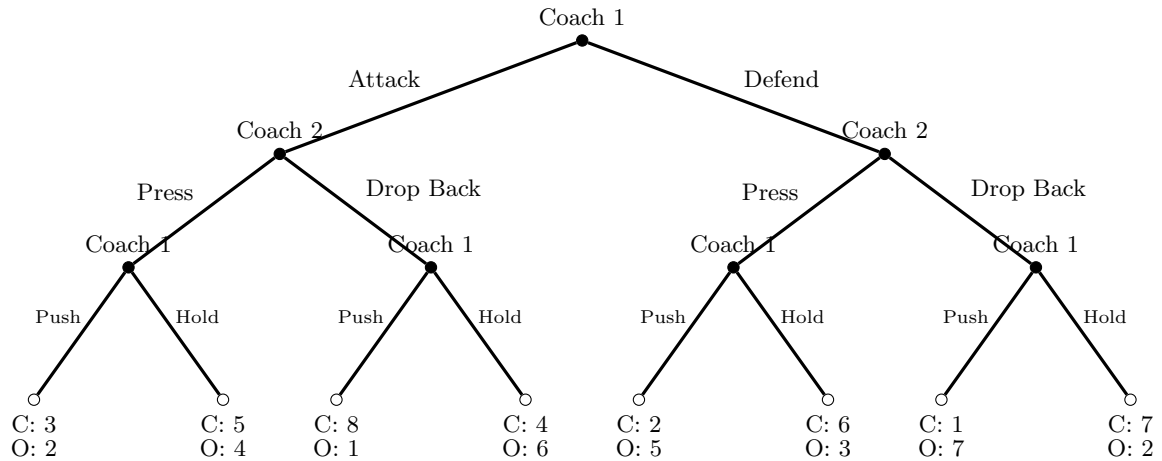
Questions

Two coffee chains, Roast and Brew, simultaneously choose whether to open a new location Downtown or in the Suburbs. Each prefers to avoid the other to minimize competition. Use the normal form representation below to answer questions 1-4.

		Brew	
		Downtown	Suburbs
Roast	Downtown	R: 2 B: 3	R: 3 B: 2
	Suburbs	R: 4 B: 2	R: 2 B: 5

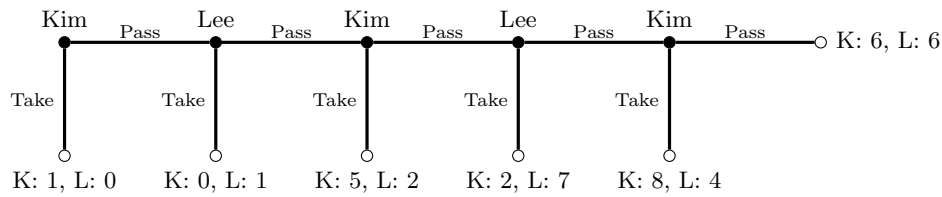
- Which of the following is true?
 - Roast has a dominant strategy to open downtown
 - Roast has a dominant strategy to open in the suburbs
 - Brew has a dominant strategy to open downtown
 - Brew has a dominant strategy to open in the suburbs
 - Neither Roast nor Brew have a dominant strategy
- Which of the following is true?
 - Roast and Brew will open downtown
 - Roast and Brew will open in the suburbs
 - Roast will open downtown and Brew will open in the suburbs
 - Roast will open in the suburbs and Brew will open downtown
 - None of the above
- Which of the following is true?
 - There exists a mixed Nash where Roast mixes with $\frac{1}{2}$ chance of opening downtown
 - There exists a mixed Nash where Roast mixes with $\frac{3}{4}$ chance of opening downtown
 - There exists a mixed Nash where Brew mixes with $\frac{1}{2}$ chance of opening downtown
 - There exists a mixed Nash where Brew mixes with $\frac{3}{4}$ chance of opening downtown
 - None of the above characterize a potential mixed Nash equilibrium
- Which of the following is true?
 - There exists a mixed Nash where Roast mixes with $\frac{1}{3}$ chance of opening in the suburbs
 - There exists a mixed Nash where Roast mixes with $\frac{2}{3}$ chance of opening in the suburbs
 - There exists a mixed Nash where Brew mixes with $\frac{1}{3}$ chance of opening in the suburbs
 - There exists a mixed Nash where Brew mixes with $\frac{3}{4}$ chance of opening in the suburbs
 - None of the above characterize a potential mixed Nash equilibrium

A basketball coach (Player 1) chooses to Attack or Defend. The opposing coach (Player 2) observes and chooses to Press or Drop Back. The first coach then adjusts by choosing to Push or Hold. Use the extensive form below to answer questions 5-8.



5. How many subgames are there of this game?
 - A) 0
 - B) 1
 - C) 4
 - D) 6
 - E) None of the above
6. Which of the following is a Nash equilibrium?
 - A) Coach 1 attacks, Coach 2 always drops, and Coach 1 pushes when they attacked and holds otherwise
 - B) Coach 1 defends, Coach 2 always presses, and Coach 1 pushes after defend/press but holds after defend/drop, attack/press, and attack/drop
 - C) Coach 1 attacks, Coach 2 always presses, and Coach 1 holds after attack/press but pushes after attack/drop, defend/press, and defend/drop
 - D) Coach 1 defends, Coach 2 drops back at defend and presses at attack, and Coach 1 holds after defend/drop and attack/press but pushes after attack/drop, and holds after defend/press
 - E) None of the above are Nash equilibria
7. Which of the following is a subgame perfect Nash equilibrium (SGPE)?
 - A) Coach 1 defends, Coach 2 presses at defend and drops back at attack, Coach 1 then holds no matter what Coach 2 does
 - B) Coach 1 defends, Coach 2 always presses, and Coach 1 always holds
 - C) Coach 1 defends, Coach 2 always presses, Coach 1 holds after defend/press and defend/drop, and pushes after attack/press and attack/drop
 - D) Coach 1 defends, Coach 2 drops at attack and presses at defend, and Coach 1 holds after defending and pushes after attacking
 - E) None of the above are a subgame perfect Nash equilibrium
8. What are the equilibrium payoffs of this game?
 - A) Coach 1 gets 5, Coach 2 gets 4
 - B) Coach 1 gets 6, Coach 2 gets 3
 - C) Coach 1 gets 7, Coach 2 gets 2
 - D) Coach 1 gets 8, Coach 2 gets 1
 - E) None of the above

Two business partners, Kim and Lee, are deciding whether to continue investing in a joint venture at each stage. Kim moves first. Use the representation of this game below to answer questions 9 and 10.



9. What is the subgame perfect Nash equilibrium of this game?
 - A) Kim takes at node 1
 - B) Lee takes at node 2
 - C) Kim takes at node 3
 - D) Kim takes at node 5
 - E) None of the above
10. What is the equilibrium outcome?
 - A) K: 1, L: 0
 - B) K: 0, L: 1
 - C) K: 5, L: 2
 - D) K: 6, L: 6
 - E) None of the above
11. Which of the following best describes a dominant strategy?
 - A) A strategy that yields the highest payoff only if the other player cooperates
 - B) A strategy that yields a higher payoff than any other strategy regardless of what the other player does
 - C) A strategy that is only optimal when the other player is also playing their best response
 - D) A strategy that maximizes the total payoff across both players
 - E) None of the above
12. Which of the following best describes a Nash equilibrium?
 - A) An outcome where both players are playing their dominant strategies
 - B) An outcome where no player can improve their payoff by a one-shot deviation
 - C) An outcome that maximizes the total payoff across all players
 - D) An outcome where both players earn equal payoffs
 - E) None of the above

Practice Midterm

Intermediate Microeconomic Theory

Instructor: Colin Adams

Name: _____

Date: _____

This is a closed note, closed book exam. You have 75 minutes to complete this exam. The exam has a total of 100 points. You may not use a phone or outside materials. Academic dishonesty will result in a zero and will be reported.

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Questions

Multiple Choice

Questions 1–15 are multiple choice worth 3 points each. Each question has only one correct answer. Circle the letter of your chosen answer, as unclear or multiple selections will be marked incorrect.

1. Which of the following best describes the composite good?
 - A) A good that is made up of multiple individual goods bundled together and sold at a single price
 - B) A good that is used in the production of other goods rather than consumed directly by households
 - C) A good that captures the combined utility of all goods in a consumer's bundle simultaneously
 - D) A good that represents spending on all other goods outside of the good being studied
 - E) None of the above
2. Which of the following best describes a complete preference?
 - A) A consumer prefers more of every good to less, such that no bundle can ever be equally preferred to another
 - B) A consumer's preferences are consistent such that if they prefer bundle A to B and B to C, they must prefer A to C
 - C) A consumer's preferences do not change as their income or the prices of goods change
 - D) A consumer who prefers bundle A to bundle B will continue to prefer bundle A even as the prices of the goods in each bundle change
 - E) None of the above
3. Which of the following situations is an example of a preference being transitive, but not complete over boots, sandals, shoes, and flip flops?
 - A) A consumer prefers boots to sandals, sandals to shoes, but prefers shoes to boots
 - B) A consumer prefers boots to sandals and sandals to shoes and therefore prefers boots to shoes, but is unable to compare any of these flip flops
 - C) A consumer prefers boots to sandals and sandals to shoes but is unsure whether they prefer shoes or boots, despite having worn both
 - D) A consumer can compare any two of these options and always prefers the one with the higher price
 - E) None of the above
4. Stew has the following preferences across bundles of games (G) and movies (M). Which of the following is correct?
$$(10G, 9M) \succ (8G, 11M) \succ (7G, 12M)$$
 - A) The preference is monotone
 - B) The preference is not monotone
 - C) There is not enough information to determine if the preference is monotone
 - D) None of the above
5. Which of the following may be described as the change in total utility resulting from consuming an additional unit of a good?
 - A) Marginal utility
 - B) Total utility
 - C) Diminishing marginal returns
 - D) Marginal rate of substitution
 - E) None of the above
6. If a consumer's income doubles and all prices double, the budget set will do which of the following?
 - A) Shift outward
 - B) Shift inward
 - C) Pivot away from the origin
 - D) Remain unchanged
 - E) None of the above

7. Which of the following is not true of an indifference curve?
 - A) Indifference curves slope downward
 - B) Indifference curves can intersect when a consumer is indifferent between two bundles on different curves
 - C) Indifference curves that are further from the origin represent higher levels of utility
 - D) The slope of an indifference curve at any point represents the marginal rate of substitution between the two goods
 - E) All of the above are true
8. An individual's demand function depends only on which of the following?
 - A) The consumer's income and the prices of goods
 - B) The prices of goods and the consumer's marginal rate of substitution at their current bundle
 - C) The prices of goods and the total utility the consumer receives from their optimal bundle
 - D) The prices of goods and the consumer's budget line intercepts
 - E) None of the above
9. Suppose the price of a normal good increases. The income effect of that good will cause its quantity demanded to do what?
 - A) Increase
 - B) Decrease
 - C) Remain unchanged
 - D) We cannot know the income effect
 - E) None of the above
10. Which of the following is true of the isoquant line?
 - A) All inputs are equal on the line
 - B) All input bundles below the line result in higher quantities
 - C) All input bundles on it cost the same
 - D) All input bundles on it result in the same quantity
 - E) None of the above
11. Which of the following best describes the marginal rate of technical substitution?
 - A) The rate at which a consumer is willing to trade one good for another while maintaining the same level of utility
 - B) The ratio of the price of capital to the price of labor
 - C) The additional output a firm receives from employing one additional unit of labor while holding capital constant
 - D) The rate at which the market will exchange capital for labor based on current input prices
 - E) None of the above
12. Apple currently produces 1,000 iPads with only 150 machines and 300 labor hours. Apple is able to produce 4,000 iPads with 450 machines and 1,200 labor hours. Which of the following best describes Apple's returns to scale?
 - A) Apple has increasing returns to scale
 - B) Apple has constant returns to scale
 - C) Apple has decreasing returns to scale
 - D) Apple may have either increasing or decreasing returns to scale
 - E) We cannot determine Apple's returns to scale
13. Which of the following is true of a firm with constant returns to scale?
 - A) The firm has decreasing average fixed cost
 - B) The firm's total cost doubles when output doubles
 - C) An equal increase in all inputs leads to a proportional increase in output
 - D) An equal increase in all inputs leads to a less than proportional increase in output
 - E) None of the above

For questions 14-15, consider Chris who has \$1,200 and may purchase bacon for \$8 per pound or ham for \$6 per pound.

14. Suppose Chris already purchased 20 pounds of ham, how much bacon can Chris buy at a maximum?
- A) 112
 - B) 120
 - C) 135
 - D) 150
 - E) None of the above
15. Ham goes on sale at Walmart. You can now buy 2 pounds of ham for \$10. Which of the following bundles is affordable? Note: You can still purchase a single pound of ham for \$6.
- A) 120 pounds of bacon and 50 pounds of ham
 - B) 125 pounds of bacon and 45 pounds of ham
 - C) 130 pounds of bacon and 50 pounds of ham
 - D) 140 pounds of bacon and 30 pounds of ham
 - E) None of the above

Free Response

Questions 16–30 are free response worth a total of 55 points. The point value for each question is indicated. Partial credit will be given based off your work in the event of an incorrect final answer.

Maya has \$200 to spend on either tea (T) or coffee (C). Tea costs \$3 and coffee \$2. Maya has the utility function below. Use this information to answer questions 16-18.

$$U(A, B) = 3T^{\frac{1}{2}} + 2C^{\frac{1}{2}}$$

16. What is Maya's marginal rate of substitution between tea and coffee? (4 points)

17. Draw Maya's budget set. (3 points)

18. What is Maya's optimal bundle? (4 points)

Rachel has \$270 to purchase CDs (C) at \$3 each or vinyl records (R) at \$6. Rachel's preferences are represented by the utility function below. use this information to answer questions 19-21.

$$U(C, R) = 2\sqrt{C} + \sqrt{R}$$

19. What is Rachel's marginal utility of CDs and Records? (4 points)

20. What is Rachel's optimal bundle? (3 points)

21. What is Rachel's marginal utility of CDs at her optimal bundle? (4 points)

Alex has \$10,000 and may purchase either laptops (L) for \$200 each or textbooks (B) for \$40 each. Alex currently has 20 laptops and 150 textbooks. Use this information to answer questions 22–25. Responses to questions 22 and 23 may be included in one figure.

22. Draw Alex's initial scenario. (3 points)
23. The price of textbooks suddenly decreases to \$25. Draw Alex's new situation. Note: Label Alex's new optimal bundle on the figure. You do not need to know the exact amounts of laptops and textbooks at this new optimal bundle. (4 points)
24. Based off of your answer to question 23, what are the total, substitution, and income effects of the price change? (4 points)
25. Based off of your answer to question 23, are textbooks a normal or inferior good for Alex? (4 points)

A builder wants to build 12 homes. The builder can either hire workers (L) for \$8 an hour or rent equipment (K) for \$2 per hour. Their production function is represented below. Use this information to answer questions 26-29.

$$Q = K^{\frac{1}{2}} + 2L^{\frac{1}{2}}$$

26. What is the builder's marginal productivity of capital and labor? (4 points)
27. What is the builder's marginal rate of technical substitution? (3 points)
28. What is the optimal amount of capital (K) and labor (L) for this builder? (4 points)
29. What is the builder's minimum cost to produce 12 homes? (3 points)

30. Suppose there are three consumers of soda. Each of the consumers' demand functions are given below. Illustrate the aggregate demand for soda using these three demand functions. (4 points)

$$1 : P = 40 - 4Q$$

$$2 : P = 40 - 2Q$$

$$2 : P = 20 - 2Q$$

Practice Final

Intermediate Microeconomic Theory

Instructor: Colin Adams

Name: _____

Date: _____

This is a closed note, closed book exam. You have 75 minutes to complete this exam. The exam has a total of 100 points. You may not use a phone or outside materials. Academic dishonesty will result in a zero and will be reported.

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Questions

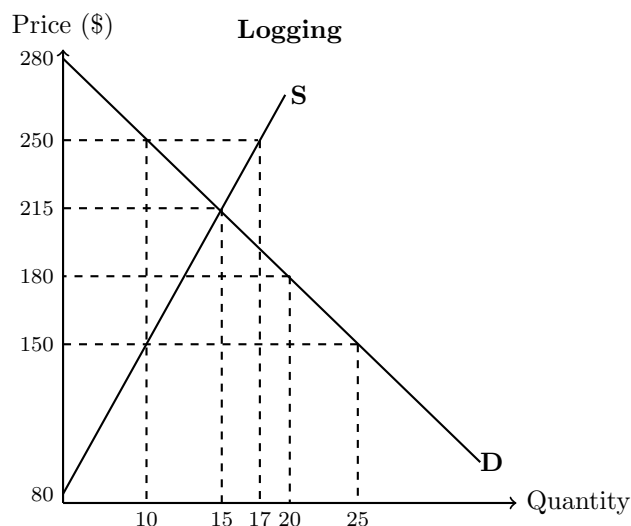
Multiple Choice

Questions 1–20 are multiple choice worth 3 points each. Each question has only one correct answer. Circle the letter of your chosen answer, as unclear or multiple selections will be marked incorrect. Any answers not indicated on the test packet will not be considered.

1. Which of the following is a characteristic of a monopoly?
 - A) Identical goods
 - B) Large barriers to entry
 - C) Price taker
 - D) Many buyers and a few sellers
 - E) None of the above
2. Consider a firm engaged in perfect competition. Which of the following is true of this firm?
 - A) They have no economic profits
 - B) They have positive economic profits
 - C) They become price searchers
 - D) They face a downward sloping demand curve
 - E) None of the above
3. Who has the sole goal of maximizing social welfare by reducing market failures such as externalities?
 - A) Firms
 - B) Consumers
 - C) Players in a game
 - D) All citizens
 - E) None of the above
4. When considering who bears the burden of a tax, economists care only of which of the following?
 - A) Actual incidence
 - B) Statutory incidence
 - C) Consumer surplus
 - D) Producer surplus
 - E) None of the above
5. Which of the following taxes is likely to create the most deadweight loss?
 - A) A tax on insulin which has nearly perfectly inelastic demand ($\varepsilon \approx 0$)
 - B) A tax on gasoline which has an elasticity of demand of $\varepsilon = 0.2$
 - C) A tax on international flights which have an elasticity of demand of $\varepsilon = 1.2$
 - D) A tax on luxury handbags which have an elasticity of demand of $\varepsilon = 3$
 - E) All of the taxes above will create nearly identical deadweight loss
6. Which of the following best explains why the Ramsey rule is considered a second-best solution?
 - A) It raises less revenue than a lump-sum tax
 - B) A lump-sum tax would raise the same revenue with no deadweight loss
 - C) It creates more deadweight loss than taxing all goods equally
 - D) It ignores the equity concerns of lower-income households
 - E) None of the above

7. Suppose a local government wants to raise funds to fund a new school. They can raise these funds via either a tax on gasoline which has an elasticity of 0.3 or water which has an elasticity of 0.1. How much should gasoline be taxed relative to water according to the Ramsey rule?
- Gasoline should be taxed half that of water
 - Gasoline should be taxed the same as water
 - Gasoline should be taxed 33.3% more than water
 - Gasoline should be taxed three times more than water
 - None of the above
8. Which of the following is true of a market with positive externalities?
- The socially optimal quantity equals the market quantity
 - The socially optimal quantity is less than the market quantity
 - The socially optimal quantity is more than the market quantity
 - We do not have enough information to determine the relationship between market and the socially optimal outcome
 - None of the above
9. Which of the following markets is most likely to have negative externalities?
- Staplers
 - Watches
 - Fireworks
 - Keychains
 - Phone cases
10. Which of the following is a potential fix for a market with positive externalities?
- Production quota
 - Pigouvian subsidy
 - Emissions tax
 - Emissions quota
 - None of the above are potential visits
11. Which of the following best describes a Pigouvian tax?
- A tax equal to the external marginal cost in order to restore allocative efficiency
 - A tax on inelastic goods designed to raise revenue with minimal deadweight loss
 - A tax equal to the total social cost of production in order to restore allocative efficiency
 - A lump-sum tax imposed on firms that produce negative externalities
 - None of the above describe a Pigouvian tax

For problems 12-13, consider the market for logging as displayed below.



12. Suppose the market logging has a socially optimal quantity of 10. What Pigouvian tax should a social planner put on this market?
- A) \$70
 - B) \$80
 - C) \$150
 - D) \$215
 - E) None of the above
13. Suppose this market is now taxed. Which of the following is true?
- A) Consumers are affected more
 - B) Producers are affected more
 - C) Consumers and producers are affected equally
 - D) We cannot know if consumers or producers are affected more
 - E) None of the above
14. Which of the following is a reason why the US generally utilizes emissions quotas in place of production quotas?
- A) Emissions quotas target negative externalities of consumption
 - B) Emissions quotas promote technological advancements
 - C) Emissions quotas have no monitoring burden
 - D) Emissions quotas don't consider price
 - E) None of the above
15. Relative to a monopolist, a market operating in perfect competition will have which of the following?
- A) Lower quantity
 - B) Higher prices
 - C) Higher efficiency
 - D) Lower consumer surplus
 - E) None of the above
16. Which term refers to firms charging exactly a consumers willingness to pay to increase profits?
- A) First degree price discrimination
 - B) Second degree price discrimination
 - C) Third degree price discrimination
 - D) Premium pricing
 - E) None of the above
17. Which of the following best describes third degree price discrimination?
- A) A firm charging different prices to different groups of consumers
 - B) A firm charging each consumer exactly their willingness to pay
 - C) A firm offering different pricing tiers based on quantity purchased
 - D) A firm charging a higher price for a premium version of a product
 - E) None of the above describe third degree price discrimination

18. YouTube offers access to their platform for free if you have an account. With a free account, you watch ads before, during, and after most videos. YouTube also offers the option to pay \$10 per month access to their platform ad free. Which type of price discrimination does this best represent?
- A) First degree
 - B) Second degree
 - C) Third degree
 - D) Price gouging
 - E) None of the above
19. Which of the following is true of a Nash equilibrium?
- A) No player can be made better off
 - B) It is the socially optimal outcome
 - C) There are no dominant strategies
 - D) There is at least one profitable deviation
 - E) None of the above
20. Which of the following best describes a charity auction in which all individuals submit their bids into a box during an event?
- A) A simultaneous move game with complete information
 - B) A simultaneous move game with incomplete information
 - C) A sequential move game with complete information
 - D) A sequential move game with incomplete information
 - E) None of the above

Free Response

Questions 21–28 are free response worth a total of 40 points. The point value for each question is indicated. Partial credit will be given based off your work in the event of an incorrect final answer.

21. The city of Tallahassee needs to raise \$15,000 in tax revenue and can tax electricity (good 1) and airline tickets (good 2). Electricity has an elasticity of demand $\varepsilon_1 = 0.5$ and airline tickets has that of $\varepsilon_2 = 1.5$. Currently 300 units of electricity and 600 airline tickets are being purchased each month. What are the optimal tax rates on each good if raising \$15,000 in tax revenue is our only goal? (6 points)

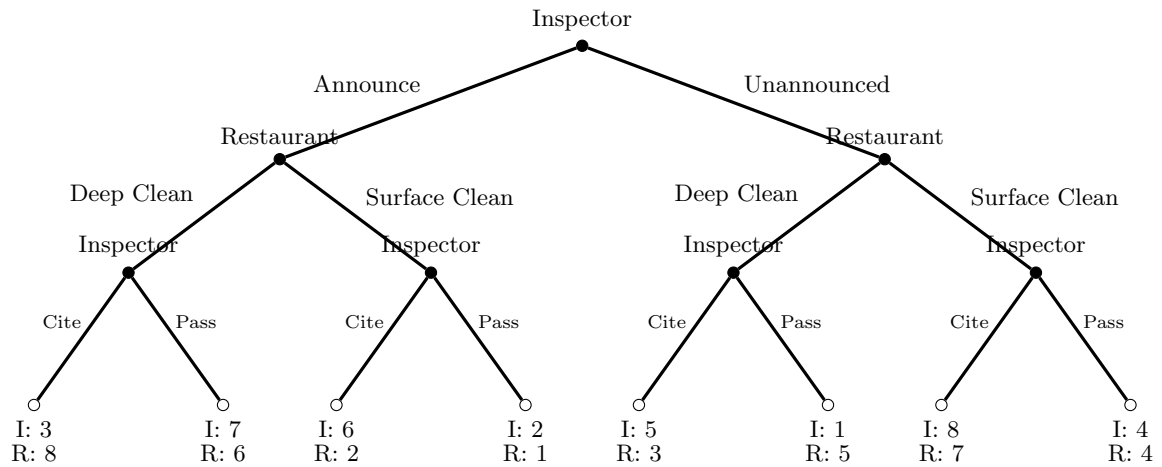
A firm is simultaneously choosing its level of output, High or Low, while a regulator is choosing whether to Audit or not. The payoff matrix below gives profits to the firm and enforcement value to the regulator, with the firm as the row player and the regulator as the column player.

		Regulator	
		Audit	No Audit
Firm	High	F: 3 R: 2	F: 5 R: 5
	Low	F: 4 R: 4	F: 6 R: 3

22. Does either player have a dominant strategy? Explain why or why not briefly. (4 points)

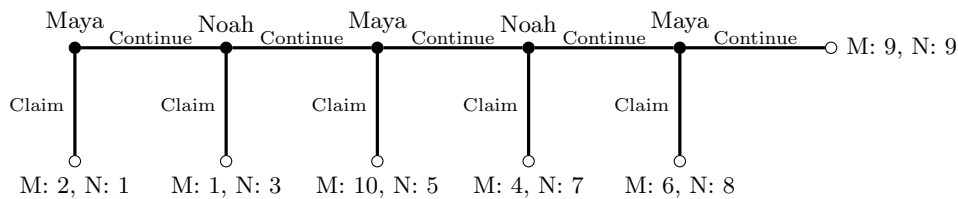
23. Identify all Nash equilibria. Make sure to state all players' strategy for each equilibria. (6 points)

A city health inspector is deciding how to conduct a restaurant inspection. The inspector moves first, choosing to announce the visit in advance or show up unannounced. The restaurant then decides whether to deep clean or surface clean. The inspector then decides whether to issue a citation or pass the restaurant. The extensive form representation of this game is given below.



24. How many subgames does this game have? (2 points)
25. Find the subgame perfect Nash equilibrium. State the full set of strategies, equilibrium outcome, and payout for each player. (7 points)
26. Find a Nash equilibrium which is not sequentially rational. Explain why this equilibrium is not sequentially rational. (6 points)

Two students, Maya and Noah, are collaborating on a research paper over five rounds. They alternate turns, with Maya moving at odd-numbered nodes and Noah at even-numbered nodes. At each node, the current student can claim sole credit (ending the collaboration) or continue. If neither claims credit, both receive authorship on a co-authored paper. This game is represented below.



27. Find the subgame perfect Nash equilibrium. State the full set of strategies, equilibrium outcome, and payout for each player. (7 points)

28. Both players would prefer the terminal outcome (9,9) to the equilibrium outcome. Why does the game not reach it? (2 points)