EECS 151/251 A Discussion 1

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About Me

- 2nd Year PhD Student in Computer Architecture
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- Lived in: Louisiana, Virginia, Rhode Island, Massachusetts, California
- Hobbies: Music, Movies/Film, Cooking, Basketball

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How these discussions will work

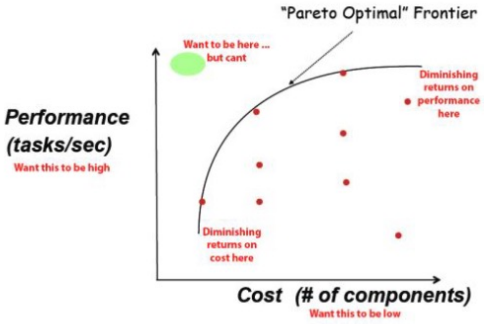
- The emphasis of these discussion will be to do practice problems
- I will briefly introduce topics covered in lecture, but we will do problems together in discussion

Content

- Pareto Optimality
- Moore's Law / Dennard Scaling

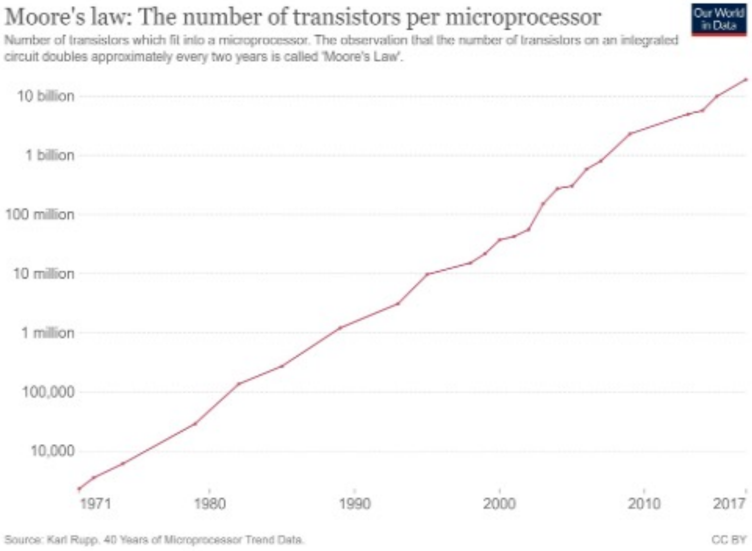
Pareto Optimal Frontiers

- Picking the best options considering all the tradeoffs you have in your design.
- Usually, in chip performance you want to:
  - Maximize frequency (chip speed)
  - Minimize Cost (of development/parts)
  - Minimize Energy Usage (financial/battery)



Moore's Law

- Number of transistors in microchips doubles approx. every two years
- However, this law did not work on it's own …



Moore's law: The number of transistors per microprocessor

Number of transistors which fit into a microprocessor. The observation that the number of transistors on an integrated circuit doubles approximately every two years is called 'Moore's Law'.

Source: Karl Rupp. 40 Years of Microprocessor Trend Data.

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Dennard Scaling

- Power costs of the chip would also scale exponentially and all chips would overheat, so we need Dennard Scaling
- Ideal Dennard Scaling scales other components of the chip proportional to the transistor dimension

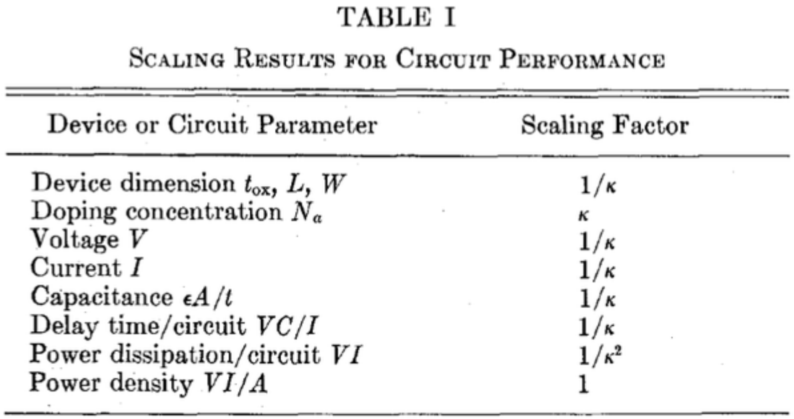


TABLE I

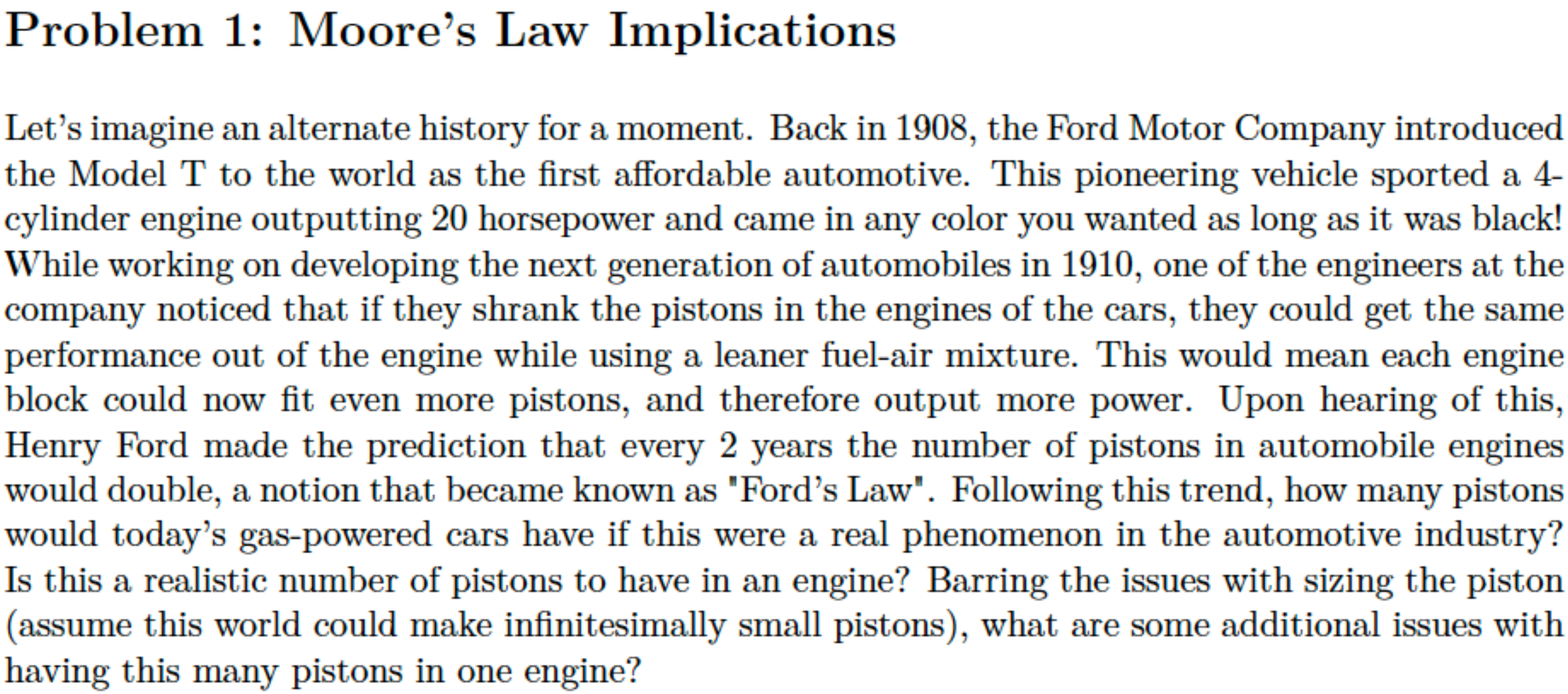
SCALING RESULTS FOR CIRCUIT PERFORMANCE

Device or Circuit Parameter	Scaling Factor
Device dimension t_{ox}, L, W	$1/\kappa$
Doping concentration N_a	κ
Voltage V	$1/\kappa$
Current I	$1/\kappa$
Capacitance $\epsilon A/t$	$1/\kappa$
Delay time/circuit VC/I	$1/\kappa$
Power dissipation/circuit VI	$1/\kappa^2$
Power density VI/A	1

Sample Problems

- First, we will work on each problem alone for 5ish minutes
- Then break into groups of 3–4 and discuss your solutions for 5 minutes
- I’ll have one the groups share their answer and we’ll go over as a class

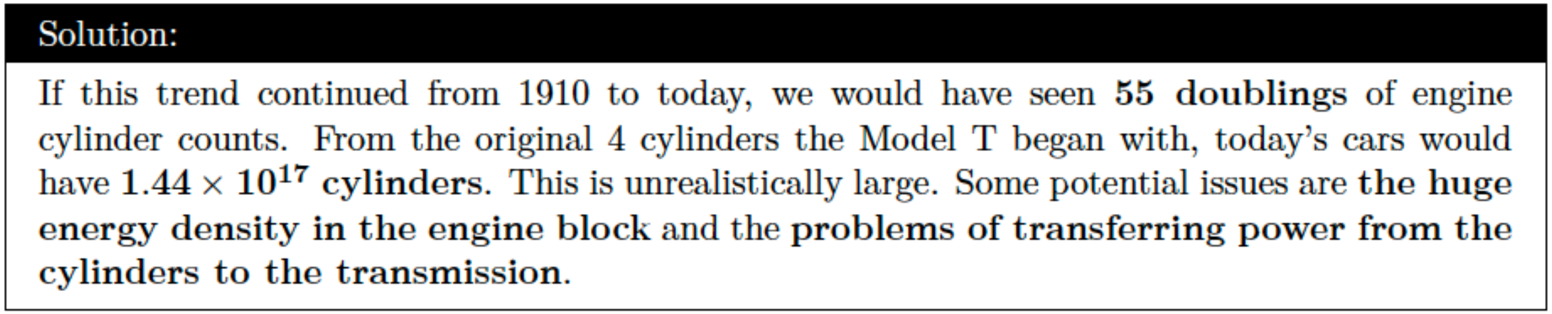
Problem 1:



Problem 1: Moore’s Law Implications

Let’s imagine an alternate history for a moment. Back in 1908, the Ford Motor Company introduced the Model T to the world as the first affordable automotive. This pioneering vehicle sported a 4-cylinder engine outputting 20 horsepower and came in any color you wanted as long as it was black! While working on developing the next generation of automobiles in 1910, one of the engineers at the company noticed that if they shrank the pistons in the engines of the cars, they could get the same performance out of the engine while using a leaner fuel-air mixture. This would mean each engine block could now fit even more pistons, and therefore output more power. Upon hearing of this, Henry Ford made the prediction that every 2 years the number of pistons in automobile engines would double, a notion that became known as "Ford’s Law". Following this trend, how many pistons would today’s gas-powered cars have if this were a real phenomenon in the automotive industry? Is this a realistic number of pistons to have in an engine? Barring the issues with sizing the piston (assume this world could make infinitesimally small pistons), what are some additional issues with having this many pistons in one engine?

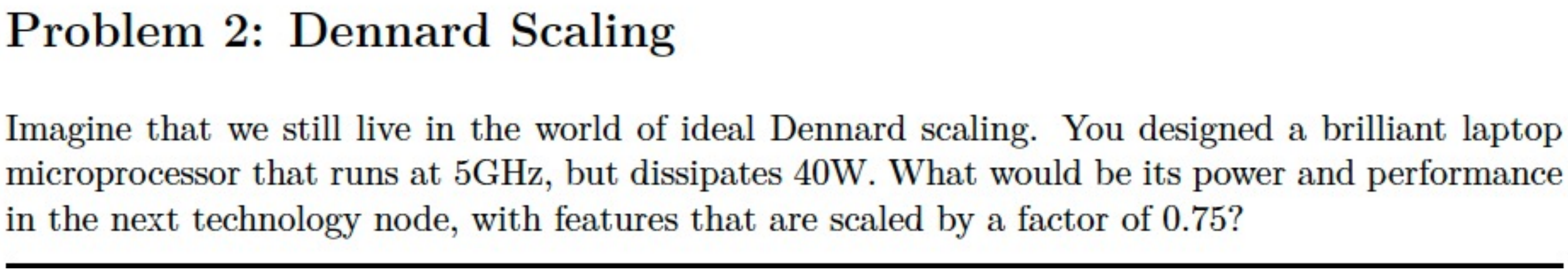
Problem 1: Solution



Solution:

If this trend continued from 1910 to today, we would have seen **55 doublings** of engine cylinder counts. From the original 4 cylinders the Model T began with, today's cars would have **1.44×10^{17} cylinders**. This is unrealistically large. Some potential issues are **the huge energy density in the engine block** and the **problems of transferring power from the cylinders to the transmission**.

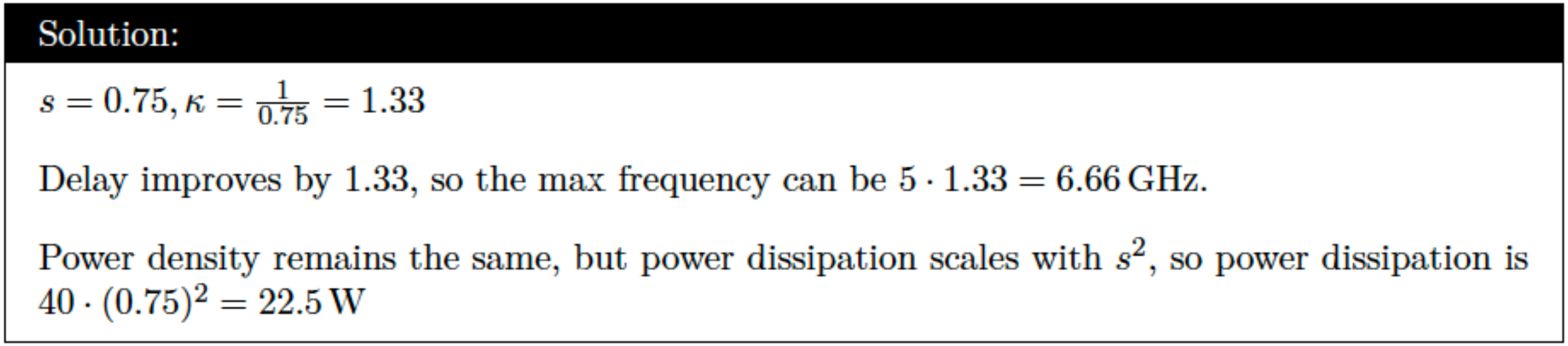
Problem 2:



Problem 2: Dennard Scaling

Imagine that we still live in the world of ideal Dennard scaling. You designed a brilliant laptop microprocessor that runs at 5GHz, but dissipates 40W. What would be its power and performance in the next technology node, with features that are scaled by a factor of 0.75?

Problem 2: Solution



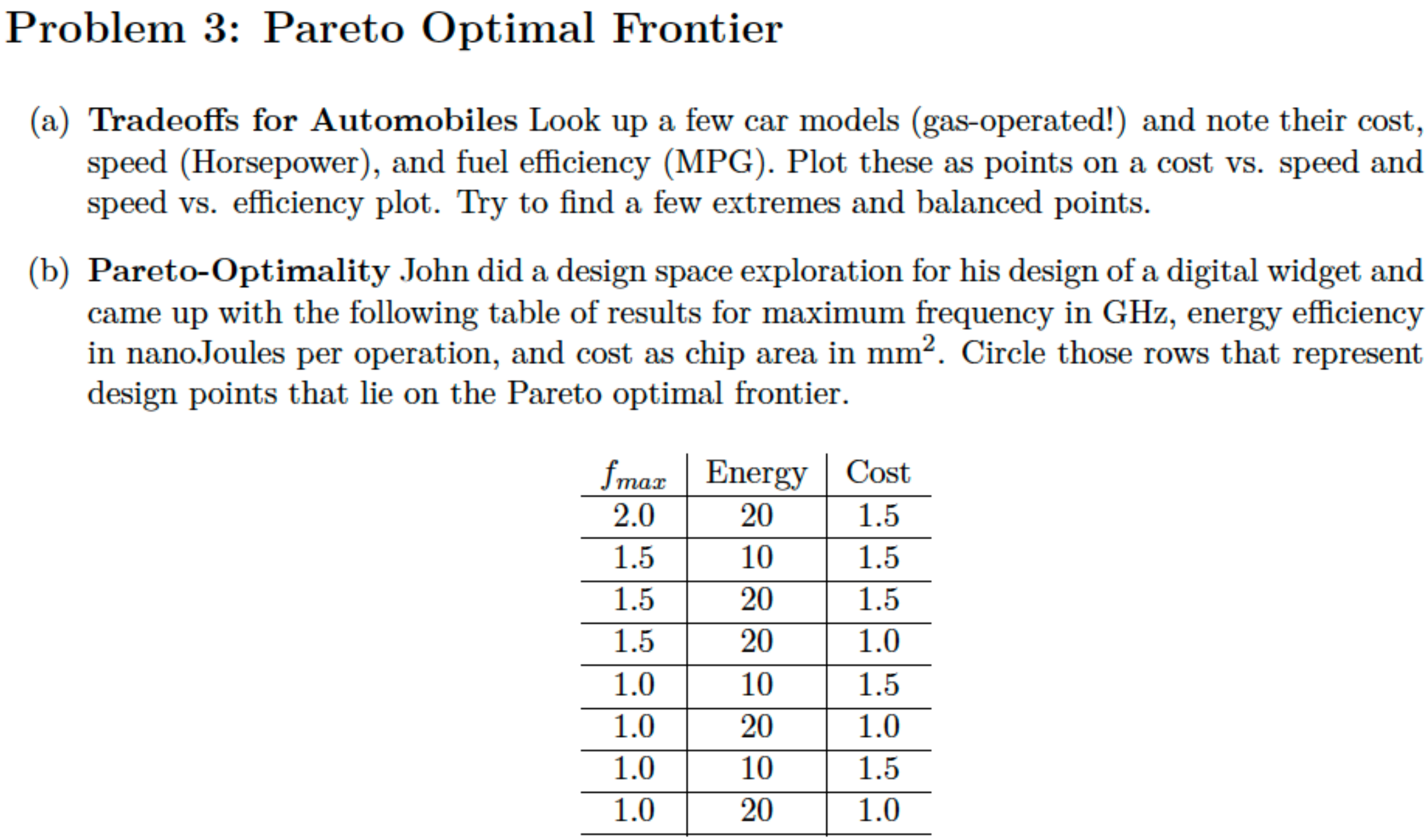
Solution:

$s = 0.75, \kappa = \frac{1}{0.75} = 1.33$

Delay improves by 1.33, so the max frequency can be $5 \cdot 1.33 = 6.66\,\text{GHz}$.

Power density remains the same, but power dissipation scales with s^2, so power dissipation is $40 \cdot (0.75)^2 = 22.5\,\text{W}$

Problem 3:



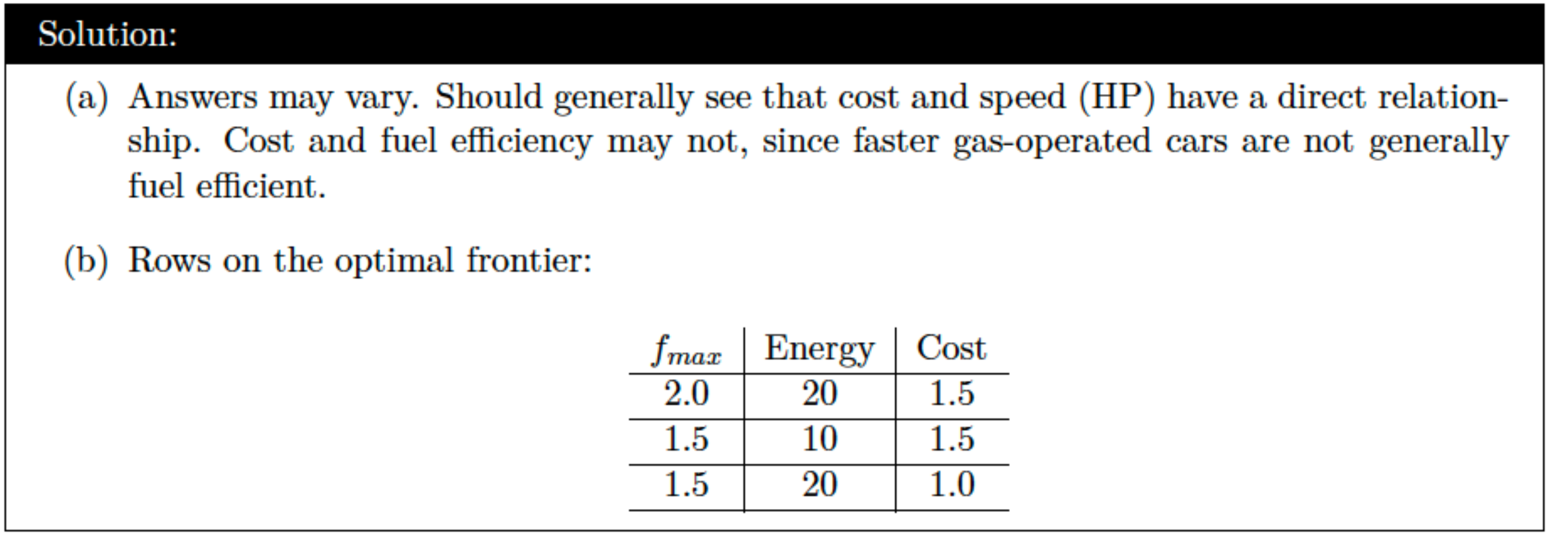
Problem 3: Pareto Optimal Frontier

(a) **Tradeoffs for Automobiles** Look up a few car models (gas-operated!) and note their cost, speed (Horsepower), and fuel efficiency (MPG). Plot these as points on a cost vs. speed and speed vs. efficiency plot. Try to find a few extremes and balanced points.

(b) **Pareto-Optimality** John did a design space exploration for his design of a digital widget and came up with the following table of results for maximum frequency in GHz, energy efficiency in nanoJoules per operation, and cost as chip area in mm^2. Circle those rows that represent design points that lie on the Pareto optimal frontier.

f_{max}	Energy	Cost
2.0	20	1.5
1.5	10	1.5
1.5	20	1.5
1.5	20	1.0
1.0	10	1.5
1.0	20	1.0
1.0	10	1.5
1.0	20	1.0

Problem 3: Solution

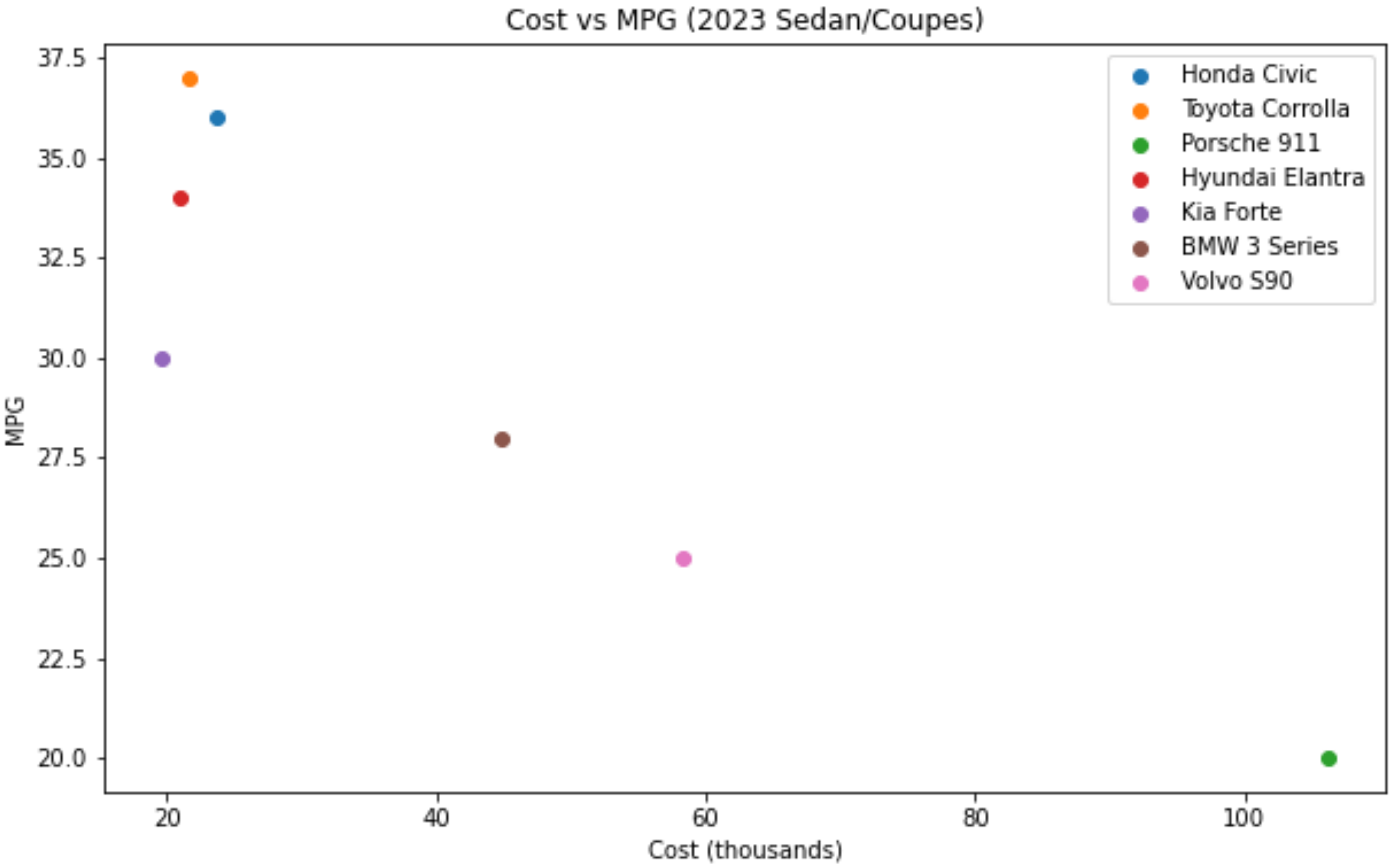


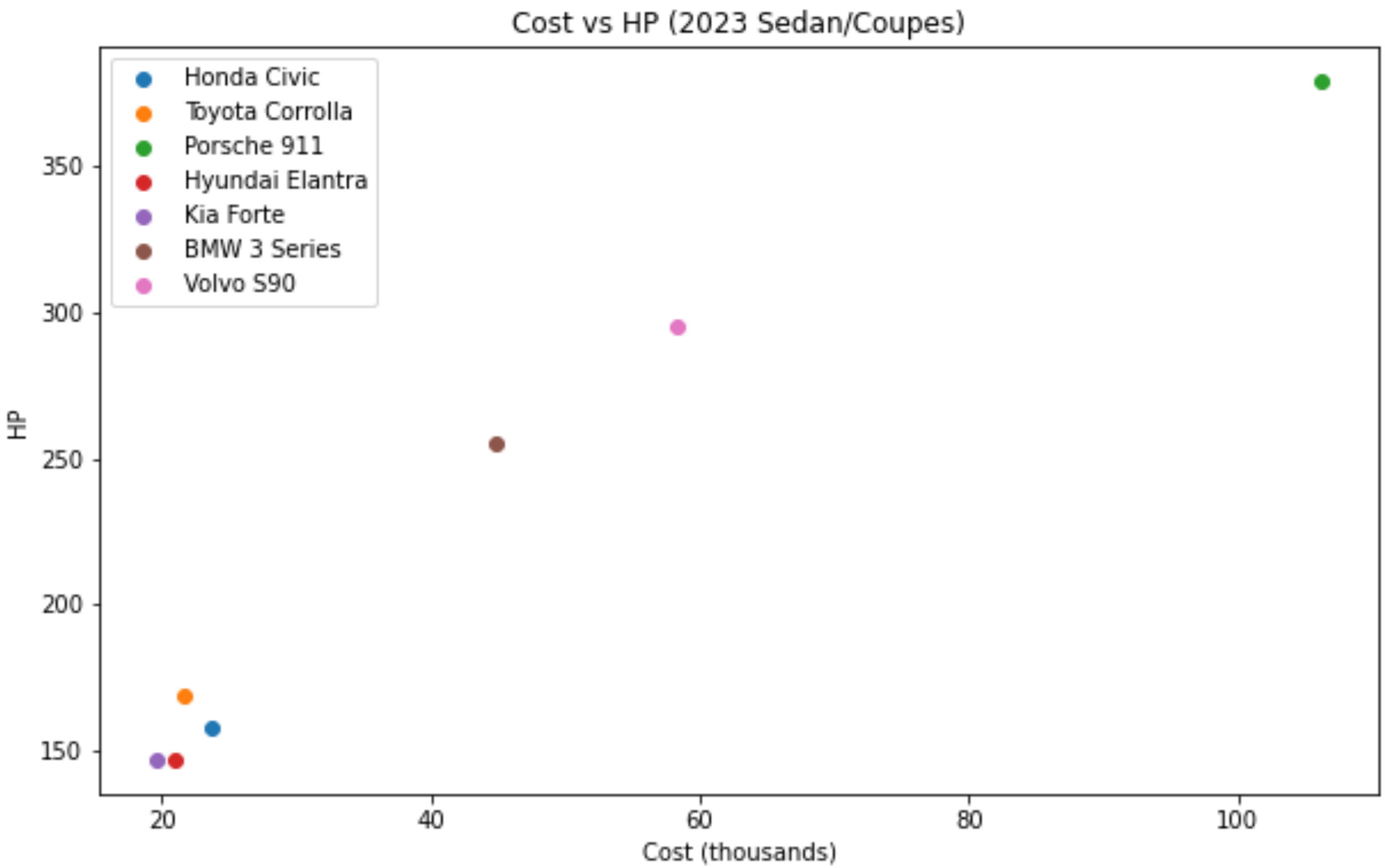
Solution:

(a) Answers may vary. Should generally see that cost and speed (HP) have a direct relationship. Cost and fuel efficiency may not, since faster gas-operated cars are not generally fuel efficient.

(b) Rows on the optimal frontier:

f_{max}	Energy	Cost
2.0	20	1.5
1.5	10	1.5
1.5	20	1.0


Cost vs MPG (2023 Sedan/Coupes)
MPG
37.5
35.0
32.5
30.0
27.5
25.0
22.5
20.0
20
40
60
80
100
Cost (thousands)
Honda Civic
Toyota Corrolla
Porsche 911
Hyundai Elantra
Kia Forte
BMW 3 Series
Volvo S90



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