Finalist Submission

The 2025 ROSENTHAL PRIZE
for Innovation and Inspiration
in Math Teaching

The PI Pursuit: Design, Discover, and Drive!

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Big Idea

A student testing their hoverboard on a 1.50m track.

In this lesson, students literally roll out the number pi. Students design and test hoverboards and cars whose wheels must travel exact distances in a whole number of revolutions. To succeed, they must uncover the relationship between a circle's diameter and its circumference and apply it in a real-world context of Electric Vehicle (EV) tire wear and precise engineering. Not only that, but they also uncover the diverse culture of pi through exploration of mathematicians such as Madhava and Emma Haruko Iwao.

This lesson requires minimal, inexpensive materials and preparation. Intended mainly for grade 7 but readily adaptable for grades 6–8, it is highly replicable. This lesson begins with a simple build and expands into challenges of increasing sophistication, from measuring to designing vehicles that work for multiple track lengths or any track size. Students enter as curious builders and leave as mathematicians, engineers, and scientists.

The lesson embodies the Standards for Mathematical Practice. Students reason quantitatively, model with mathematics, and persevere as they iterate on their designs. Its low-floor, high-ceiling structure ensures every learner can engage, whether through trial and error, targeted calculation, or generalizable solutions. Lesson extensions invite deep number-theory explorations.

By uniting discovery with design, this lesson shows students that mathematics is not just something to listen to but something to do. It nurtures precision, creativity, and joy, giving all learners a tangible, memorable encounter with pi. This 60 to 120 minute experience transforms a standard curriculum expectation into an unforgettable engineering adventure.

Overview

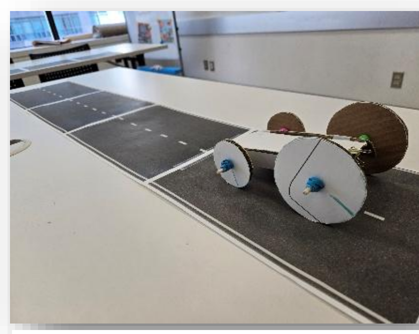
Hoverboard on a 1.5m track.

In this innovative low-floor, high-ceiling math challenge, students will design a two-wheeled hoverboard and then upgrade it into a custom-built car to travel an exact or two exact, pre-determined distance(s). But success isn't just about building. It's about mathematical precision.

Students can choose any wheel size, but to reach the destination exactly, the wheel's circumference must be a factor of the distance. Vehicles must stop precisely at the finish line no more, no less verified by a visible wheel mark. Along the way, students will create their own wheels, measure diameters and circumferences, and uncover the mysterious constant that connects them: pi.

Activity Sequence:

1. Build a hoverboard that reaches the destination in exactly the right distance(s). With a whole number of wheel revolutions.
2. Upgrade to a car with different-sized front and rear wheels that reaches the destination.
3. Ensure the front wheels revolve a prime number more times than the rear wheels.
4. Explore the diverse culture of the discovery and exploration of pi.
5. Connect the activity to the real world.



Car on a 1m track.

Students will encounter mathematical concepts such as ratio, GCF, LCM, prime numbers, and even explore the Madhava series: an early derivation of pi. They'll also learn about Emma Haruka Iwao, the trailblazing female scientist who computed over 100 trillion digits of pi.

This engaging activity connects geometry, design, and number theory to the real-world concept of EV range (travelling an exact distance) and tire wear (whole number of wheel revolutions). With creative freedom to decorate their vehicles and test multiple solutions, students are empowered to explore math through building, movement, and discovery.

There are two versions of this lesson. The original lesson will be roughly 60 minutes long and the extended version will require at least 120 minutes.

Teacher Preparation

Part I: Track Preparation

Prepare 2 tracks of different lengths. Two different length tracks is a differentiation strategy so that advanced students have an extra challenge. The tracks should be longer than 30 inches depending on how large the available cardboard is for your students. You want to ensure that the wheel sizes aren't too small. Here are some useful measurements:

Track Size	Required Cardboard Size for each Wheel	Revolutions
~ 30 in	~ 4 in x 4 in	3
~ 40 in	~ 4 in x 4 in	4
~ 60 in	~ 10 in x 10 in	2
~ 80 in	~ 4 in x 4 in	4

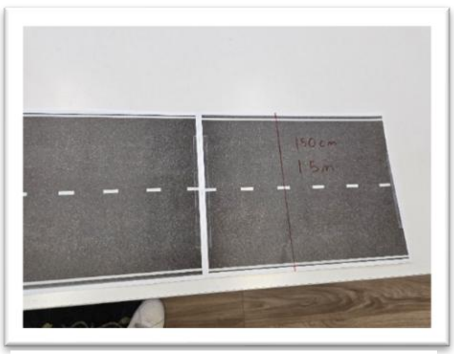


Figure 1. Track with 150cm mark labeled.

It is useful to have more than one of the same tracks. With more tracks, more students can test their vehicles simultaneously. It may be also more engaging with tracks that have road images shown in Figure 1. These tracks were created by printing copies of road pictures (**Appendix B**) and taping them together side by side.

Part II: Materials Preparation

- Cardboard (medium thickness)
- Scissors
- Compass
- Pencils
- Rulers
- Skewer or Dowel (1 for hoverboard axle)
- Rubber Bands (to make the connection tight between wheels and axle)
- Plain Paper (for design or body of hoverboard)
- Calculators
- Printout of 1st **Completion Checklist** for each student
- Printout of **Handout 1** for each student
- Printout of **Handout 3** for each student
- Printout of **Exit Card** for each student

- Markers for designing the vehicle (optional)
- Stickers for designing the vehicle (optional)

Materials for extended lesson:

- Laptop/computer or printout of information on Emma Haruko and Madhava's series (**Appendix A**)
- Printout of **Handout 2** for each student
- Printout of 2nd **Completion Checklist** for each student

Part III: Prepare Instructions and Demonstration

Provide students with the following background information:
They are replicating a situation with EVs and tire wear. They want to reach a destination with exact distance and a whole number of wheel revolutions to start. There are additional challenges, and they get progressively harder. It's critical for them to find the ratio of diameter to circumference to make the correct sized wheels. The instructions to creating their vehicles are on the handouts. Emphasize that the connection between wheels and axle must be tight and all other connections should be loose. You can read through the objectives on handouts 1 and/or 2. Also remind students that there are two different sized tracks. A high ceiling challenge is to make a vehicle that can travel both tracks with whole number of revolutions for each track. Having a hoverboard and car premade to demonstrate the movement of the vehicle on the track may be a helpful visual for students.

Part IV (Optional): Prize Category Preparation

Teachers can provide prizes for students' hoverboards or cars. Here are some examples:

- Most accurate distance
- Most creative design
- Best tributes to Madhava and Emma (designs on vehicle)
- Most stable vehicle
- Most versatile that can travel any track of any length in a whole number of wheel revolutions
- Other

Anticipated Student Strategies and Misconceptions

The following are some challenges teachers may face when running this lesson with their students:

1. Students may go to the trial-and-error route instead of finding the pi ratio. At a certain point it may be helpful to do the calculations with the students.
2. Students may have difficulty using a compass. You may need to demonstrate multiple times or assist students with using the compass correctly.
3. Students may make the connection at the wheel and axle loose. If it's loose you may need to use rubber bands or glue. The dowel/skewer needs to spin together with the wheels as one unit.
4. Students may have difficulty with making the wheel circular. Having cut-outs of circles to trace may be helpful. Warning, this should be used as the last resort or else the discovery aspect will be lost.
5. Some students may take longer than 1 hour to create and test the hoverboard. At this point having other students complete the other challenges may be best. This activity is made so that all students can go at their own pace and complete the handouts at their own pace.
6. Advanced students may finish early. Have them create a hoverboard that can travel any whole number distance (in feet) track in a whole number of wheel revolutions as an extra challenge. (Answer is on the last question of Handout 3 of the **Teacher Cheat Sheet**)

Assessment Map

Assessment	Student Actions	Teacher Actions
Formative Handout 1	• Students are finding the ratio of diameter to circumference. • Students are finding ways to calculate a wheel size so that they can travel an exact distance with a whole number of revolutions. • Students are using rulers and compass to cutout circles and create hoverboard. • Students are testing hoverboard to see if it works on given track.	• Check if students got ratio correct of Handout 1 Part II. Getting the correct ratio is fundamental to completing the rest of the lesson. • Check for revolutions and wheel marks when students are testing hoverboard.
Formative Handout 2	• Students will explore Madhava and Emma Haruko Iwao to understand the cultural diversity and characteristics of pi. • Students are finding another circumference that will allow exactly a prime number of revolutions different from the hoverboard wheels. • Students are creating a car by extending their hoverboard.	• Check if students understand Madhava and Emma's contributions. • Check if students can find a circumference that will rotate exactly a prime number more or less than the hoverboard wheels. • Check for revolutions and wheel marks when students are testing.
Student Self-Assessment Handout 3	• Students record their learning steps in Handout 3 Question 1.	• Provide students with prompts to help them start with their reflections.
Summative Exit Card Handout 3 Part I	• Students complete consolidation of Handout 3 with class and teacher. • Students complete exit card.	• Consolidate using Part I of Handout 3. • Provide students with Exit Card.

Lesson Timing

1 Hour Lesson (Hoverboard only)

Event	Description	Timing
Introduction and Objectives	Introduction and demonstrations by the teacher. Teacher will also go over part I of **Handout 1** with the class.	10 minutes
Handout 1	Students complete **Handout 1** and create a hoverboard.	30 minutes
Award ceremony (optional)	Announce student awards.	10 minutes
Consolidation and Homework (Handout 3)	Complete first part of **Handout 3** as a class and consolidate the formula for circumference of a circle. Students can complete the rest of the handout for homework.	5 minutes
Exit card	Students complete **Exit Card** for teacher assessment.	5 minutes

Extended: 2 Hour Lesson (Hoverboard and Car)

Event	Description	Timing
Introduction and Objectives	Introduction and demonstrations by the teacher. Teacher will also go over part I of **Handout 1** with the class.	10 minutes
Handout 1	Students complete **Handout 1** and create a hoverboard.	30 minutes
Handout 2	Students complete **Handout 2** and extend their hoverboard to a car. Please have printouts (**Appendix A**) or laptop ready for students to complete parts II and III.	60 minutes
Award ceremony (optional)	Announce student awards.	10 minutes
Consolidation and Homework (Handout 3)	Complete first part of **Handout 3** as a class and consolidate the formula for circumference of a circle. Students can complete the rest of the handout for homework.	5 minutes
Exit card	Students complete **Exit Card** for teacher assessment.	5 minutes

Curriculum Connections

This lesson is most suitable for grade 7 students but can be extended to grade 8. The common core store standard that most aligns with this activity would be 7.G.4: focusing on knowing the formula for circumference of a circle and use them to solve problems.

This lesson also implements all the Standards of Mathematical Practice (SMP) as shown in the table below.

SMP	Lesson Connection
Make sense of problems and persevere in solving them.	Students try to understand how to create wheels of a certain size so that it can travel an exact distance. They will need to persevere until they find the correct answer.
Reason abstractly and quantitatively.	Students need to quantitatively find the connection between diameter and circumference. They will also abstractly find the formula for circumference of a circle.
Construct viable arguments and critique the reasoning of others.	Students need to reason with peers on their thinking to develop the correct wheel size.
Model with mathematics.	Students use their mathematical calculations to develop a correct size for the wheels.
Use appropriate tools strategically.	Students need to use the tools strategically because it needs to travel an exact distance for two different wheel sizes. They will use compasses and rulers to make their wheels.
Attend to precision.	Students will understand that the wheel sizes will be more precise with higher precision of pi.
Look for and make use of structure.	Students will see a pattern and structure when discovering pi.
Look for and express regularity in repeated reasoning.	Students will continue to get close to the mark and repetitively try to get closer to the exact distance.

Handout 1: The Hoverboard Problem

Activity Objective

You need to create a hoverboard so that you reach the destination of exactly _________ in a whole number of wheel revolutions. The reason is that you want to ensure that your hoverboard has consistent tire wear throughout and the range of the battery. If you do not reach the destination in a whole number of revolutions, the wear will be inconsistent throughout the entire tire.

<u>Successful example:</u> you reached the destination in exactly 3 wheel revolutions.
<u>Unsuccessful example:</u> you reached the destination in 3.2 wheel revolutions.
*****For a challenge, make your hoverboard work for 2 different length tracks.

Learning Objective: Students will understand the relationship between a circle's diameter and circumference, apply multiplication, division, and GCF to solve related tasks, and become more proficient in measuring and using a compass.

Part I: Terminology (Teacher-led)

Term	Definition	Diagram/Example
Diameter		
Circumference		
Revolutions		
Radius		

Part II: The Connection Between Diameter and Circumference

Find the pattern and fill in the table. The first three have been done for you.

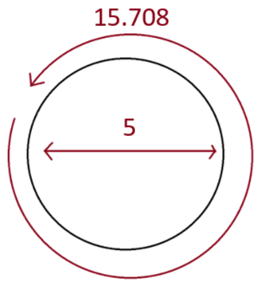
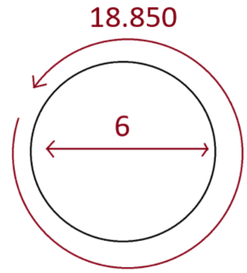
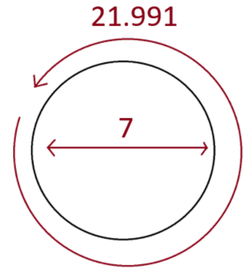
Diagram (not to scale)			
Diameter	5	6	7
Circumference	15.708	18.850	21.991

Diagram (not to scale)			
Diameter	2	3	4
Circumference			

The ratio or multiplicative factor of diameter to circumference is: ___________

Part III: The Connection Between Circumference and Distance Travelled

If a wheel has a circumference of 31 inches, what is the distance travelled after 1 revolution?

Part IV: Conclusion

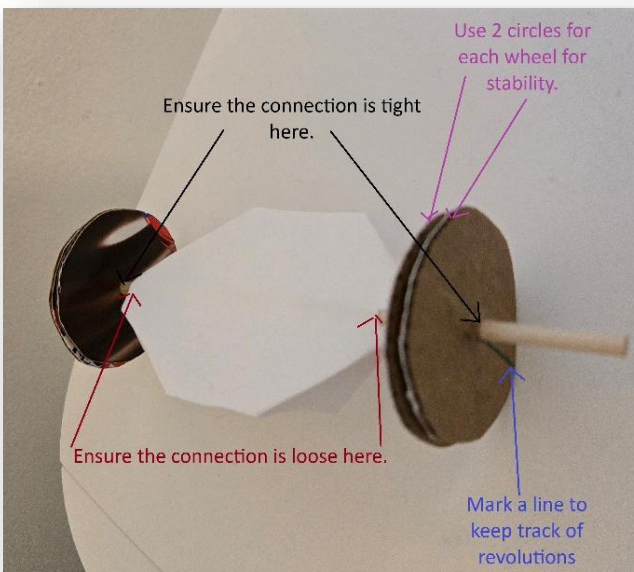
What will be the diameter of your wheel? How many revolutions will it take to reach the destination? Try out some different diameters below:

Diameter	Revolutions	Total Distance

Part V: Gather Materials and Create Hoverboard

Gather your materials and tools to develop your hoverboard:

- Cardboard
- Compass
- Ruler
- Paper
- Dowel or skewer (1)
- Scissors
- Pencil
- Calculator
- Rubber Bands
- Other colouring tools (optional)
- Stickers (optional)
- Tape (optional)
- Glue (optional)



Hoverboard Diagram.

- Try to use two circles for each wheel for stability.
- Ensure that connections are tight at the wheel and axle. If loose, please use rubber bands to tighten the connections.
- Ensure that connections are loose everywhere else.
- Make a mark on the side of the wheel to see the number of revolutions.
- You can poke a preliminary hole through the center of the wheel using the compass.

Handout 2: The Car Problem

Activity Objective

Convert your hoverboard into a car. Your car should have different sized front and rear wheels. You want to ensure that your car reaches the destination with the front and rear wheels exactly a prime number of revolutions apart.

Successful example: the front wheels rotated 7 times. The rear wheels rotated 4 times. The difference between their revolutions is 7 – 4 = 3. 3 is prime so you have succeeded.
Unsuccessful example: the front wheels rotated 6 times. The rear wheels rotated 2 times. The difference between their revolutions is 6 – 2 = 4. 4 is not prime so you have not succeeded.
*Challenge: make your car work for 2 different tracks of different lengths.

Learning Objective: Students will apply LCM, GCF, and prime number concepts to solve related tasks, and learn about the contributors to the concept of pi.

Part I: Review

How many times has your hoverboard wheels rotated to reach the destination from Handout 1: ______

Part II: Build a More Accurate Wheel

From Part A, the ratio or multiplicative factor of diameter to circumference is: _______

The more decimal places of the ratio you use, the more accurate and precise your answer.
Read the information on Madhava provided on another sheet (**Appendix A**).
Take a look at Madhava's infinite series:

$$4 \times \left(1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \cdots\right)$$

Calculate the series for 5 to 10000 terms using the table below.

Use the link for high numbered terms: https://codepen.io/leesan11/pen/VYvOLLw
Refer to other resource handout for more information on Madhava.

Number of Terms	Expression	Evaluate
5		

6		
100	No expression needed. Please use website to evaluate.	
10000	No expression needed. Please use website to evaluate.	
100000	No expression needed. Please use website to evaluate.	
1000000	No expression needed. Please use website to evaluate.	

What's the connection between the above series and the ratio from Part II?

Write this series on your car somewhere as a tribute to Madhava.

Part III: How Many Digits can you get?

Read the information on Emma provided on another sheet (**Appendix A**).
________________ is a female computer scientist who computed __________________ digits of this constant. What did she use to compute it?

This constant is called: ______ and has the symbol: _______
Write Emma's name on your car as a tribute.

Part IV: Car Wheel Measurements

What will be the diameter of your wheels? How many revolutions for the front and rear wheels will it take to reach the destination? What is the difference between their revolutions? Use the table to find the answer to these questions.

Diameter 1	Diameter 2	Circumference 1	Circumference 2	Revolutions 1	Revolutions 2	Difference

Part V: Create Your Car

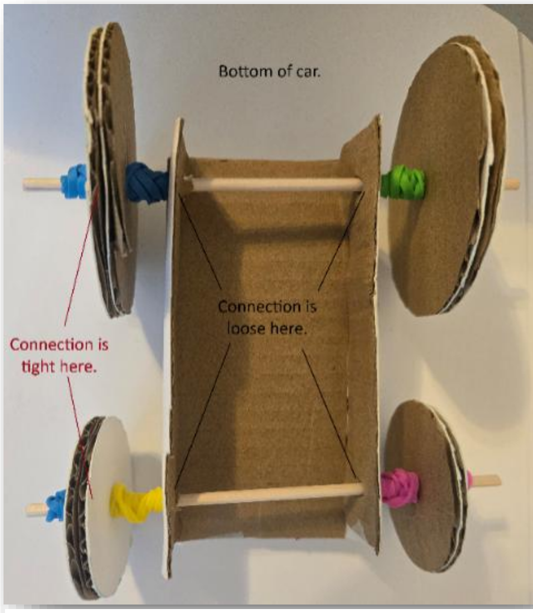


Diagram: Bottom View of Car

- Extend your hoverboard into a car.
- Use two circles for each wheel for stability.
- Ensure that the connections are tight at the wheel and axle.
- Ensure that connections are loose everywhere else.
- Make a mark on the side of the wheel to see the number of revolutions.
- Use carboard for the body.
- Ensure the body doesn’t touch the rubber bands.
- Ensure the connection of the body to the axle is extremely loose.

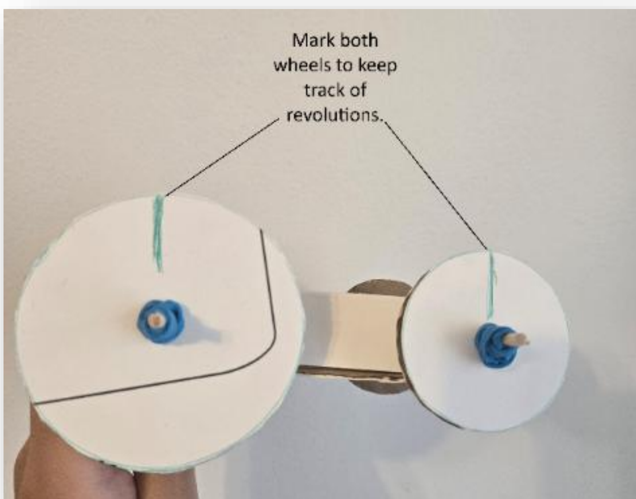


Diagram: Side View of Car

Handout 3: Consolidation, Reflections, and Applications

Consolidation: (Teacher led)

1. The formula for the circumference of a circle is:

2. What is pi? How did you discover it?

Homework/Reflections & Applications

1. How did you calculate the size of your wheels for Part A and Part B. Explain your entire process like a journal.

2. What is tire wear? Why does this happen? How many revolutions for a tire before it gets too worn? How can people tell if a tire is worn on automobiles?

3. What is the average EV range? What type of batteries do EVs use? How can the range be expanded in the future?

4. Pi is known as an irrational number; explain why it is irrational? What is the meaning of infinite?

5. Assuming that you can write one digit in half a second, how long will it take to write down 100 trillion digits of pi? In days? In years?

6. You want to reach a destination of 10 miles. What sized wheels could you have so that you reach your destination in a whole number of revolutions?

7. A car travels 20 miles at 2000 revolutions per minute (RPM) in about 10 minutes. What is the diameter of the wheels?

8. How is a car’s odometer reading measured? How does it know how many miles its travelled?

9. What sized wheels would allow you to travel any whole number destination in feet (e.g. 4500 feet) in a whole number of revolutions?

Exit Card

1. What is the connection between diameter and circumference? How did you find out?

2. If the diameter of a circle is 3 inches, what is the circumference?

3. If the circumference of a circle is 5 feet, what is the diameter?

4. If a track is 100 inches long, how many revolutions would it take a 1 inch diameter wheel to reach the end of the track?

Completion Checklist for Students

Original Lesson (60 minutes)

Please put a check beside tasks you complete.

Complete	Task
	Listened to instructions and completed part I of Handout 1 with class.
	Completed the rest of Handout 1.
	Created hoverboard that met all criteria for one or both tracks.
	If done early, completed hoverboard that met all criteria for any whole numbered track length in feet (e.g. 300ft).
	Complete first part of Handout 3 with class.
	Completed Exit Card
	Understood that the rest of Handout 3 will be homework.

Extended Lesson (120 minutes)

Please put a check beside tasks you complete.

Complete	Task
	Listened to instructions and completed part I of Handout 1 with class.
	Completed the rest of Handout 1.
	Created hoverboard that met all criteria for one or both tracks.
	Completed the rest of Handout 2.
	Created car that met all criteria for one or both tracks.
	If done early, completed hoverboard that met all criteria for any whole numbered track length in feet (e.g. 300ft).
	Complete first part of Handout 3 with the class.
	Completed Exit Card
	Understand that the rest of Handout 3 will be homework.

Teacher Cheat Sheet

Here are some sample answers that may be useful when carrying out the lesson!

Handout 1: The Hoverboard Problem

Term	Definition
Diameter	A straight line that passes through the center of a circle. The endpoints of the line must lie on the circumference of the circle.
Circumference	The total distance around the outer edge of a circle.
Revolutions	A single 360 degree turn around its center.
Radius	A straight line from the center to the circumference of a circle.

If a wheel has a circumference of 31 inches, what is the distance travelled after 1 revolution?
Answer: 31 inches

Handout 2: The Car Problem

Number of Terms	Expression	Evaluate
5	$4 \times (1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9})$	3.3396825397
6	$4 \times (1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \frac{1}{11})$	2.9760461760
100	No expression needed. Please use website to evaluate.	3.1315929036
10000	No expression needed. Please use website to evaluate.	3.1414926535
100000	No expression needed. Please use website to evaluate.	3.1415826535
1000000	No expression needed. Please use website to evaluate.	3.1415916535

Emma Haruko Iwao is a female computer scientist who computed _100 trillion_ digits of this constant. What did she use to compute it? Google cloud computing resources

This constant is called: _Pi___ and has the symbol: __π___

Handout 3: Consolidation, Reflections, and Applications

The formula for the circumference of a circle is: C = π x d

What is pi? How did you discover it?
Students should have found the ratio or the multiplicative factor from diameter to circumference to be 3.14.

What is tire wear? Why does this happen? How many revolutions for a tire before it gets too worn? How can people tell if a tire is worn on automobiles?
Tire wear is the removal of rubber from the surface over time due to friction. A tire can be used for about (50000 miles x 63360inches/mile) / (25 inch x π) = 40 356 687.90 roughly 40 million revolutions before a tire is completely worn. People use tread depth to gauge tire wear.

What is the average EV range? What type of batteries do EVs use? How can the range be expanded in the future?
The average range is 300 miles for an EV that uses lithium-ion batteries. Solid state batteries will expand range in the future.

Pi is known as an irrational number; explain why it is irrational? What is the meaning of infinite?
An irrational number cannot be expressed as a fraction of two integers. There are no two integers that could be equivalent to π. Irrational numbers in the decimal form are infinite and nonrepeating. Infinite is a quantity that is endless and without limit.

Assuming that you can write one digit in half a second, how long will it take to write down 100 trillion digits of pi? In days? In years?
0.5 s x 100 000 000 000 000 = 50 000 000 000 000 s / 86400 s/day = 578 703 703.7 days / 365 days = 1 585 489.6 years ~ 1.6 million years

You want to reach a destination of 10 miles. What sized wheels could you have so that you reach your destination in a whole number of revolutions?
Answers may vary. (10 miles / 10000 revolutions / π) x 63360inch/mile = 20.168 inches

A car travels 20 miles at 2000 revolutions per minute (RPM) in about 10 minutes. What is the diameter of the wheels?
2000 RPM x 10 min = 20 000 revolutions
20 miles / 20 000 revolutions = 0.001 miles / π = 0.0003183 miles x 63360inch/mile = 20.168 inches

How is a car's odometer reading measured? How does it know how many miles its travelled?
The odometer is calculated using the number of wheel rotations. The tire size and rotations are used to find the total distance traveled.

What sized wheels would allow you to travel any whole number distance in feet (e.g. 4500 feet) in a whole number of revolutions?
Keep the revolutions equivalent to the distance of the track. Then distance/revolution = 1 =>
π x diameter = 1 since distance/revolutions = π x diameter.
Therefore, diameter = 1/π = 0.3183 feet

Exit Card

If the diameter of a circle is 3 inches, what is the circumference? 3in x π = 9.425 in

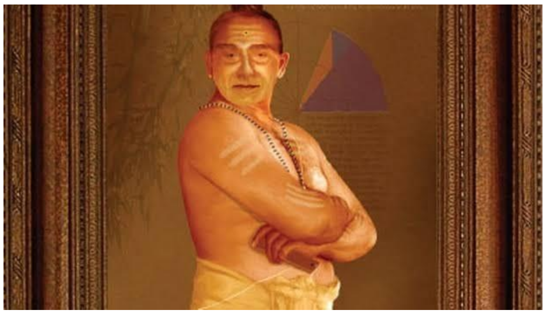
If the circumference of a circle is 5 feet, what is the diameter? 5ft/π = 1.591 ft

If a track is 100 inches long, how many revolutions would it take a 1 inch diameter wheel to reach the end of the track? 100 inches / (1in x π) = 31.83 revolutions

Appendix A

Handout 2 Part II

Madhava of Sangamagrama



Madhava of Sangamagrama. "Madhava's Infinite Series." 14th century. Illustration. Retrieved from https://medium.com/@viigyaan/the-madhava-infinite-series-and-value-of-pi-%CF%80-a387d144fbfd

Madhava was an Indian mathematician and astronomer born in the 14th century. He is known for his work on infinite series and trigonometry (O'Connor & Robertson, 2000). His major contributions include the development of infinite series, trigonometry, geometry, and algebra. He may be one of the first to use infinite series for many trigonometric functions. Madhava is believed to have developed an infinite series that allows for the calculation of pi with high accuracy. He is known to able to calculate pi up to 10 decimal places (Bag, 2012). His work contributed to the foundation of calculus and mathematical analysis (O'Connor & Robertson, 2000).

Madhava's infinite series for pi calculation is:

$$4 \times \left(1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \cdots\right)$$

Please use the following link to fill the table in Handout 2:
https://codepen.io/leesan11/pen/VYvOLLw

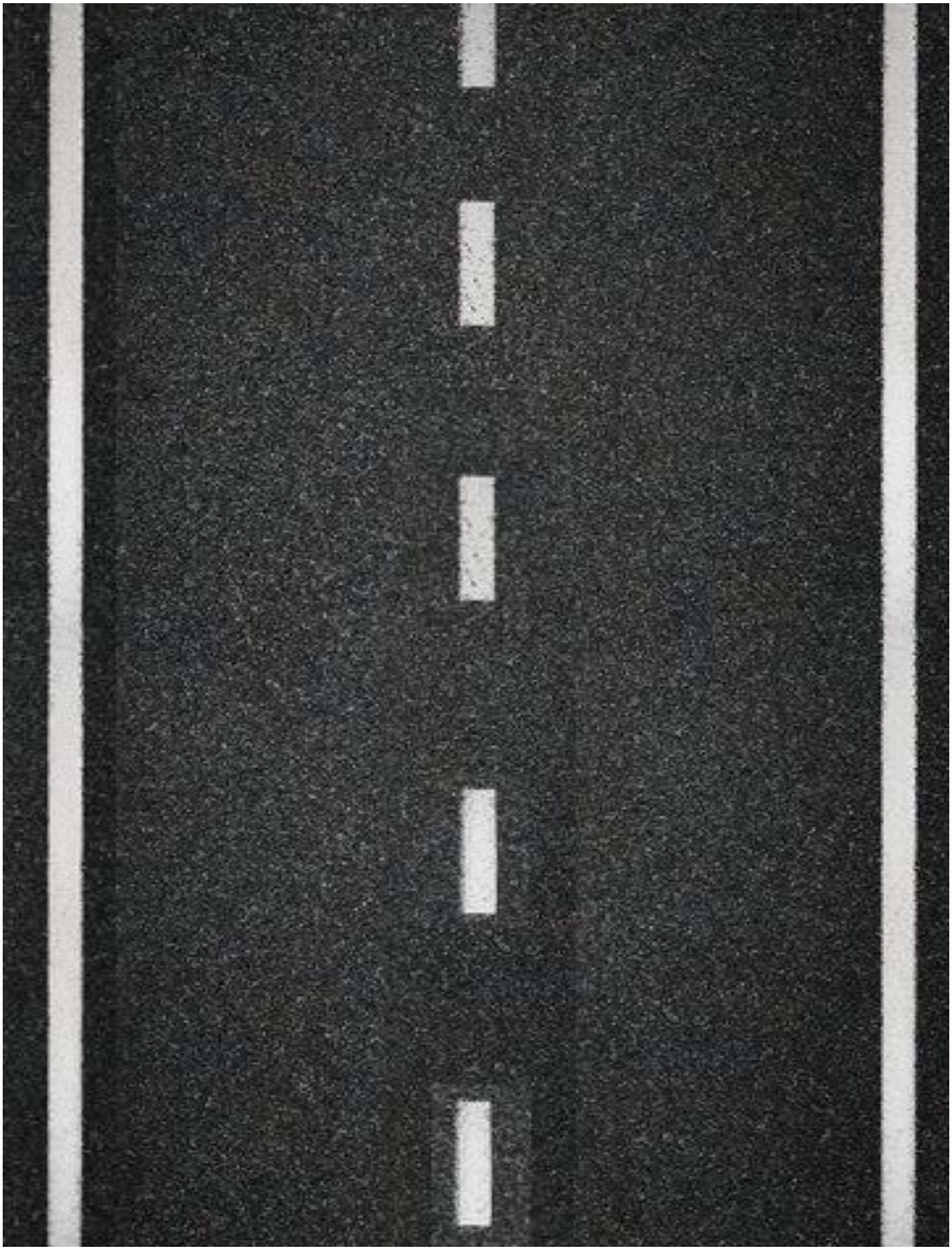
Handout 2 Part III

Emma Haruko Iwao

Iwao, Emma Haruko. "Emma Haruko Iwao." 2022. Photograph. Retrieved from https://www.bbc.com/news/technology-47524760

Emma Haruko Iwao is a Japanese computer scientist and cloud developer at Google, best known for her work in computing pi to an extraordinary number of digits (Iwao, 2022). In 2019, she calculated π to 31.4 trillion digits, and in 2022, she extended this to 100 trillion digits (Iwao, 2022). To achieve this, she utilized Google Cloud's computing resources. Her work not only set a new record but also highlighted the capabilities of modern cloud computing, demonstrating the power of cloud technology in solving complex computational problems.

Appendix B



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