THE CARLA CHRONICLES:
BACK ON TRACK

MEET THE CREW!

WARREN

A TALENTED CODER WHO OVER-THINKS THE CONSEQUENCES OF HIS ACTIONS. WARREN'S SKILLS AND DEMEANOR COMPLIMENT HANNAH PERFECTLY.

HANNAH

A GO-GETTER WITH A GIFT FOR PHYSICS AND MECHANICS. HANNAH'S ALWAYS READY TO JUMP INTO THE FRAY, EVEN IF SHE SHOULD LOOK BEFORE SHE LEAPS.

MASTER CRANK

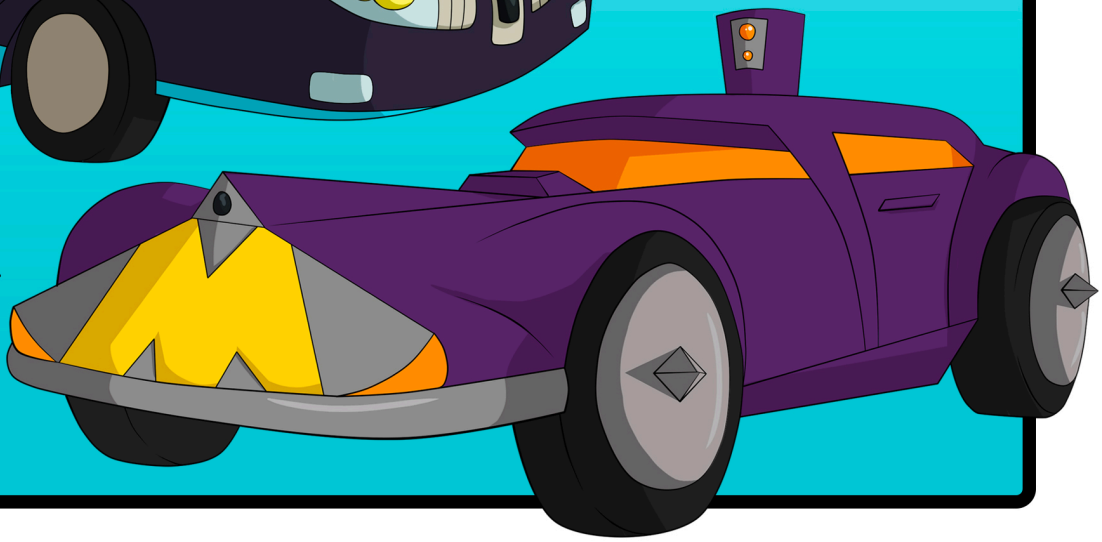
THE ZEN-LIKE PROPRIETOR OF CRANK'S JUNKYARD. MASTER CRANK'S WORDS OF WISDOM HELP CALM WARREN AND FOCUS HANNAH.

REX RAZER

A SLICK-SUITED, SLICKER-HAIRED INDUSTRIALIST, REX RAZER HAS HIS EYES ON TURNING CRANK'S JUNKYARD INTO A SLUDGE FACTORY.

CARLA

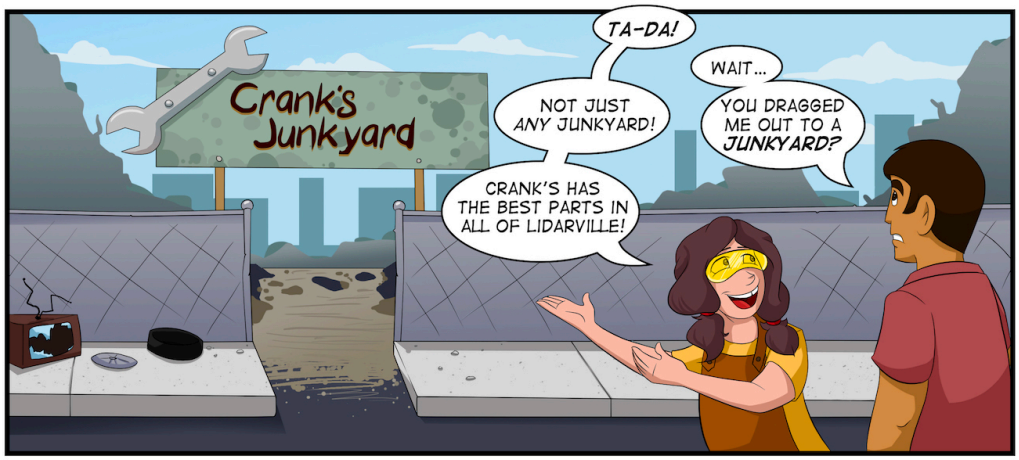
ORIGINALLY CREATED BY REX RAZER AND THEN ABANDONED, CARLA IS LOGICAL, UNSENTIMENTAL AND DETERMINED TO BECOME A TRUE SELF-DRIVING CAR.

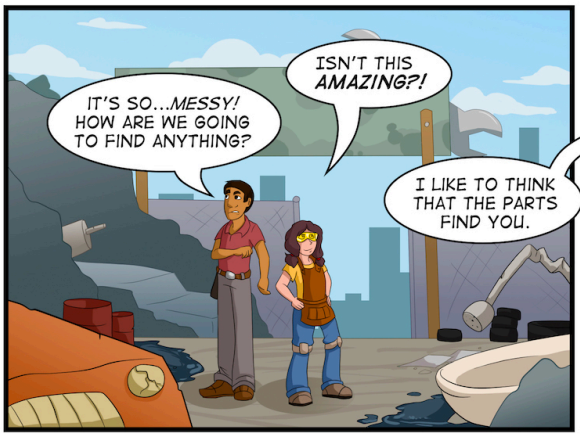


MAELSTROM

A SUPREMELY CONFIDENT STATE-OF-THE-ART SELF-DRIVING CAR THAT IS DEDICATED TO SERVING REX RAZER.

...OR IS HE?

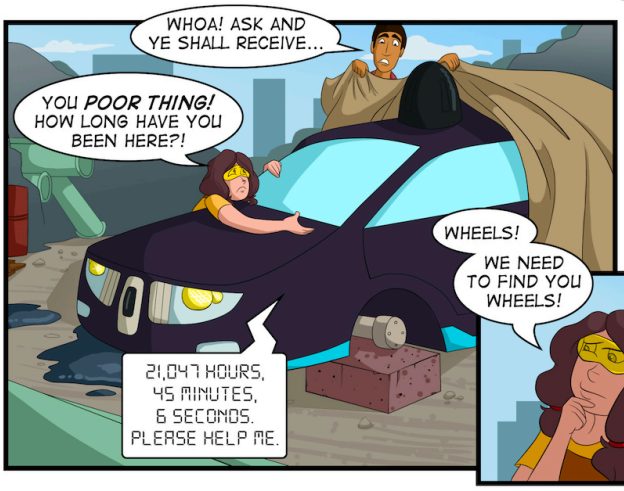

Crank's Junkyard
TA-DA!
NOT JUST ANY JUNKYARD!
CRANK'S HAS THE BEST PARTS IN ALL OF LIDARVILLE!
WAIT...
YOU DRAGGED ME OUT TO A JUNKYARD?


IT'S SO...MESSY! HOW ARE WE GOING TO FIND ANYTHING?
ISN'T THIS AMAZING?!
I LIKE TO THINK THAT THE PARTS FIND YOU.

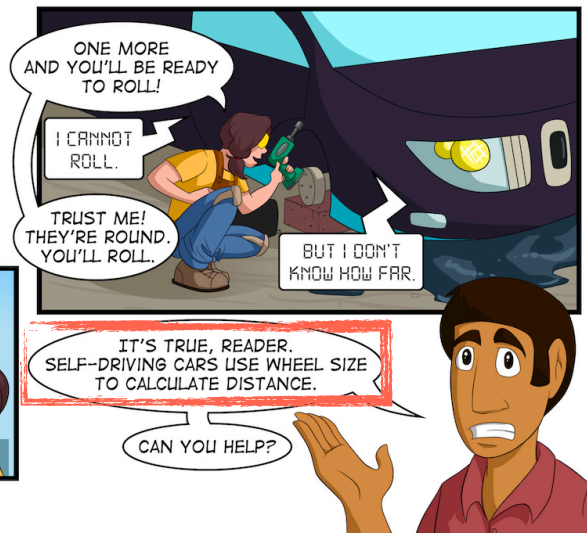

I AM MASTER CRANK. WELCOME.
I'M HANNAH! THIS IS WARREN.
WE'RE WORKING ON AN AUTONOMOUS ROBOT PROJECT!
JUST DOING OUR PART TO SPEED THE EVENTUAL ROBOT UPRISING.

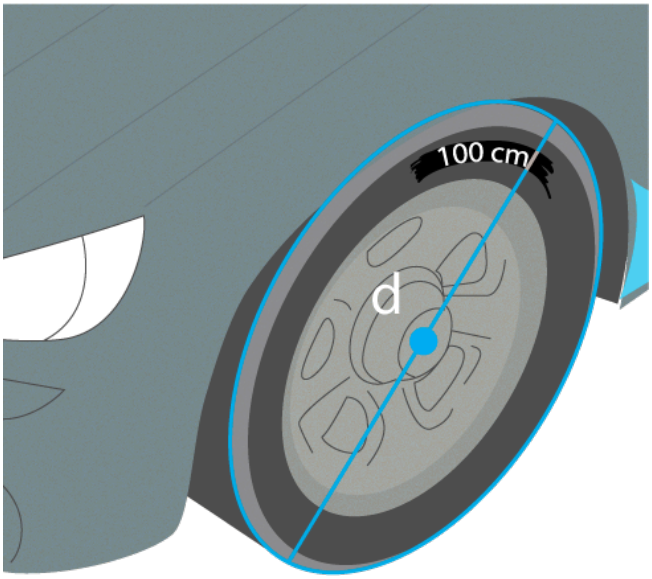

FUTURE SITE OF RAZER SLUDGE FACTORY
Another quality project by Rex Razer Inc.
BUILD THE WORLD YOU WANT. NOT THE WORLD YOU FEAR.
BUT HURRY.
TIME IS NOT ON YOUR SIDE.


DOESN'T REX RAZER HAVE ENOUGH FACTORIES?
HE ALREADY BUILDS PHONES, DISHWASHERS, SELF-DRIVING CARS
OF COURSE!! WE SHOULD BUILD A SELF-DRIVING CAR!
DID SOMEONE SAY SELF-DRIVING CAR?


WHOA! ASK AND YE SHALL RECEIVE...
YOU POOR THING! HOW LONG HAVE YOU BEEN HERE?!
21,047 HOURS, 45 MINUTES, 6 SECONDS. PLEASE HELP ME.

WHEELS! WE NEED TO FIND YOU WHEELS!


ONE MORE AND YOU'LL BE READY TO ROLL!
I CANNOT ROLL.
TRUST ME! THEY'RE ROUND. YOU'LL ROLL.
BUT I DON'T KNOW HOW FAR.
IT'S TRUE, READER. SELF-DRIVING CARS USE WHEEL SIZE TO CALCULATE DISTANCE.
CAN YOU HELP?



QUIZ QUESTION

You brush the dust off of one of Carla's new tires. The rubber on the side is raised and says:

```
Tire Diameter: 100 cm
```

About how far will Carla roll forward with **one full rotation** of her tires?

- 50 cm
- 100 cm
- ✓ 314 cm
- 500 cm

SUBMIT


SOMETHING'S GOING ON AT THAT JUNKYARD...
THAT CAR... WHY DO I KNOW THAT CAR?
I GET PARTS FROM ALL OVER LIDARVILLE, BUT A WHOLE CAR?
WELL, WHEREVER SHE'S FROM, IT'S TIME TO STRETCH HER LEGS.
I DO NOT HAVE LEGS.
HE MEANS YOUR WHEELS!
KROOOOOM
WOW... SHE'S FAST.
WAIT.
WHERE AM I?
SCREEEEEEEEEEEEEEECH
HELP.
I AM LOST.
SERIOUSLY?!
HAVE PATIENCE. SHE'S STILL FINDING HER PLACE IN THE WORLD.
THAT'S IT!
HER MAP ISN'T CONNECTED. TIME FOR SOME MORE TINKERING.


CHALLENGE TIME!

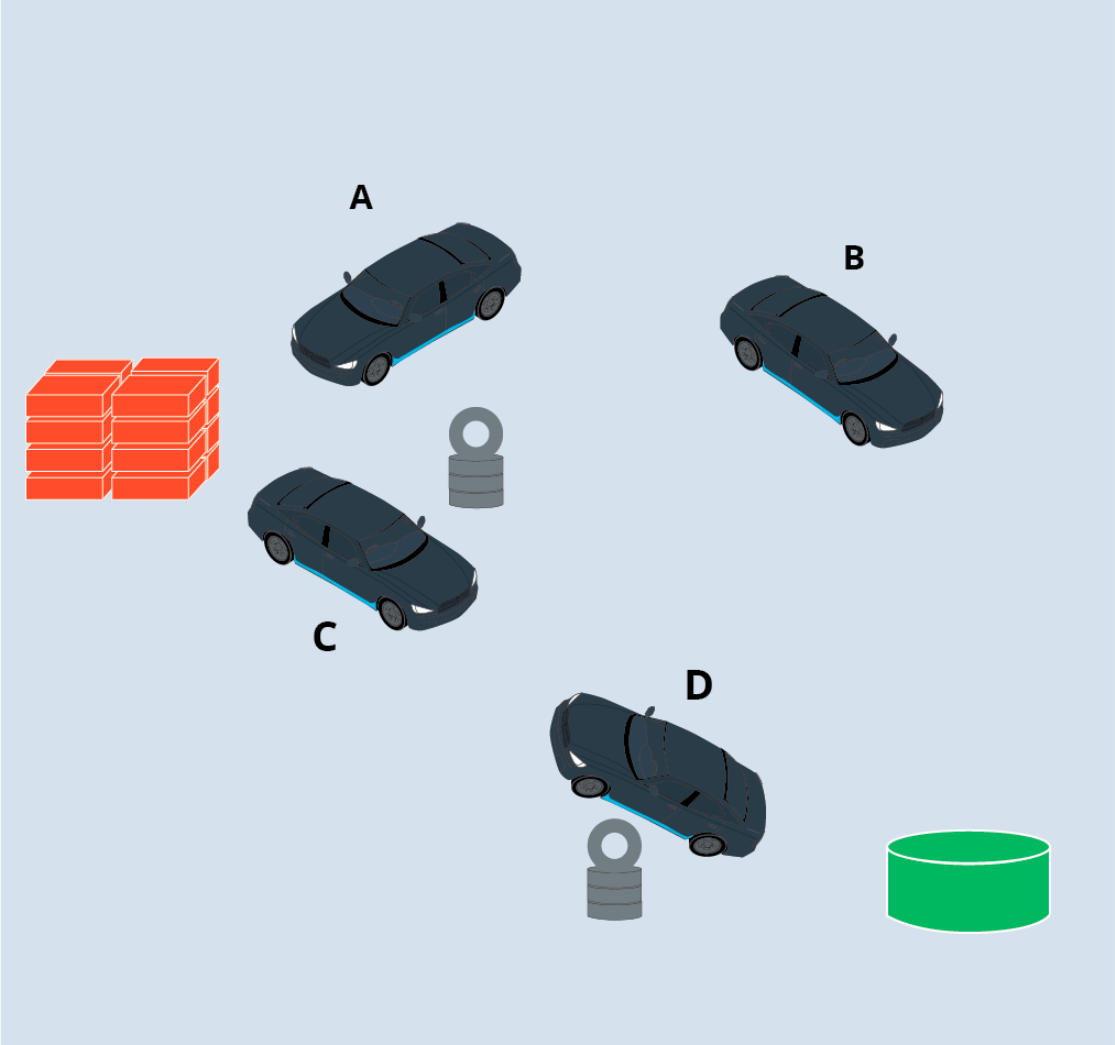
Help Carla Localize Herself

Carla is lost in the junkyard. Lying around the junkyard are two old tires, a pile of bricks, and a green bucket. Luckily, we have a map of where these are and Carla's sensors are still working.

When asked to describe what's around her, Carla replies:

*"Location unknown. I am located between a pile of bricks and a green bucket. Old tire **directly** to my left."*

Can you help Carla use this information to narrow down where in the junkyard she is likely to be?



QUESTION 1 OF 2

Based on what Carla sees, there are two locations in the junkyard where she might currently be located. Which **two** locations shown above (marked as **A**, **B**, **C**, and **D**) could be Carla's true location?

- [ ] A
- [ ] B
- [x] C
- [x] D

SUBMIT

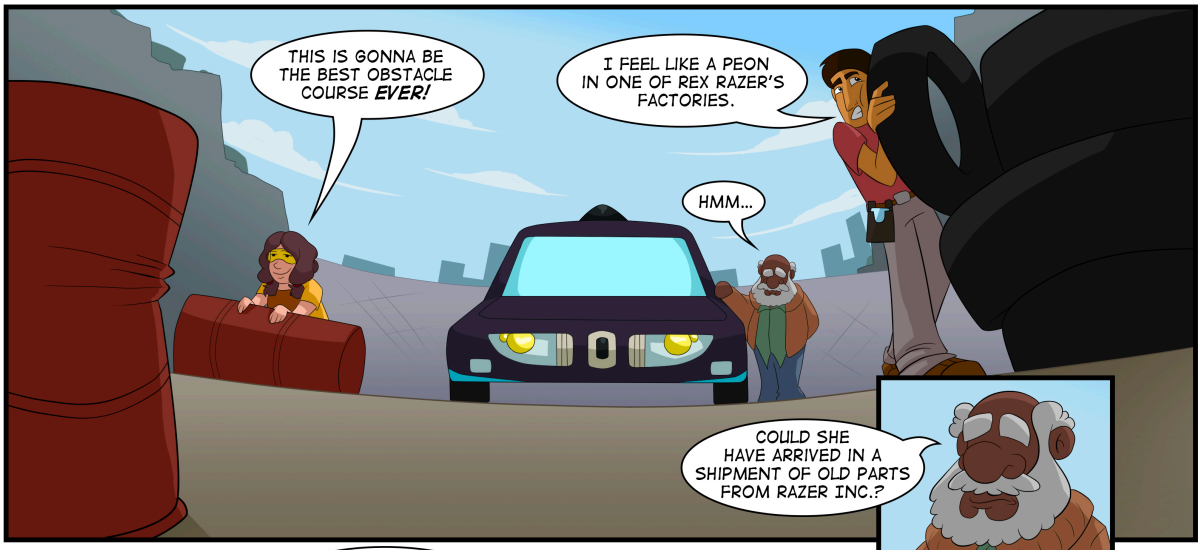
QUESTION 2 OF 2

The information Carla gave us was good, but it could have been better (but we can forgive her, after all she *did* just wake up).

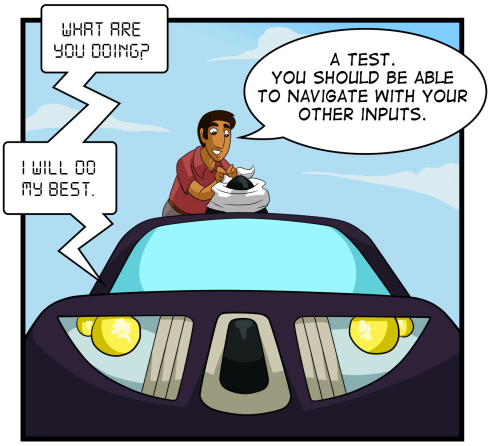
Based on what Carla's said so far you've localized her to **two** possible locations. Which of the following questions could you ask Carla to know **exactly** where she is? (there are 2 correct answers)

- [ ] How far away are you from the tire?
- [x] What's directly in front of you: the bricks or the bucket?
- [x] Are you closer to the bricks or the bucket?

SUBMIT


THIS IS GONNA BE THE BEST OBSTACLE COURSE EVER!
I FEEL LIKE A PEON IN ONE OF REX RAZER'S FACTORIES.
HMM...
COULD SHE HAVE ARRIVED IN A SHIPMENT OF OLD PARTS FROM RAZER INC.?


OF COURSE! THAT'S MY CAR!
NO ONE STEALS FROM REX RAZER.
THAT'S RIGHT, MAELSTROM.
TIME FOR OPERATION SLUDGE!


WHAT ARE YOU DOING?
A TEST. YOU SHOULD BE ABLE TO NAVIGATE WITH YOUR OTHER INPUTS.
I WILL DO MY BEST.


CRASH
WHUMP
YEAH.
I'D SAY THAT'S A D MINUS.


THAT WAS NOT GOOD.
ONLY FROM FAILURE, CAN WE FIND UNDERSTANDING.
WELL, I DON'T UNDERSTAND WHAT'S GOING ON.
I DO! IT'S THE HEAT!
ARE YOU WITH ME?

Unfortunately, Carla's tires (like any car's tires), don't always stay exactly the same size. When the outside temperature changes, the diameter of the tires will change too. This **uncertainty** shows up everywhere in self driving cars. One way to deal with it is through exploration of your environment.

For Carla, that could mean doing the following every time she "wakes up":

1. Measure the distance between herself and an object directly **behind** her.
2. Turn her wheels exactly **one full rotation**.
3. Make the same distance measurement again.
4. Use the measurements from 1 and 3 to calculate the distance traveled. This is the current **circumference** of her tires.
5. Perform the appropriate math to compute the *current* diameter of her tires.

Unfortunately, Carla has a bug in the code that performs steps 4 and 5! Help Carla drive by finding and fixing the bug!

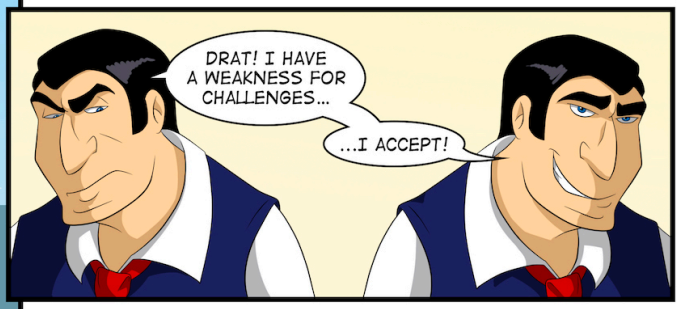
Note: If you aren't ready to program in Python yet, that's okay! You can skip this quiz and the quiz in *Challenge: Shortest Path* for now; we'll provide you some resources to brush up on Python in the next lesson (as well as going through a lot of additional Python techniques throughout the Nanodegree program).

```
1  from math import pi
2
3  def get_tire_diameter(dist_before_turn, dist_after_turn):
4      circumference = dist_after_turn - dist_before_turn
5      diameter = circumference / pi
6      return diameter
```


NEXT TIME, WARREN CAN WEAR THE BLINDFOLD.
HEY, WE ALL LEARNED SOMETHING!
I RECOGNIZE THAT FACE.
YES YOU DO...
CARLA.
FUTURE SITE OF RAZER
SLUDGE FACTORY
Another quality project by Rex Razer Inc.

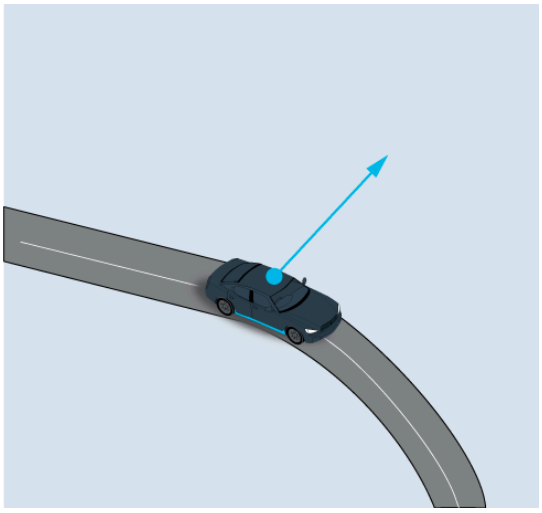

CARLA?
I BUILT HER. I NAMED HER.
THEN TRY THIS. I'M TAKING MY CAR AND DESTROYING THIS JUNKYARD!
IT'S CUTE. UNEXPECTED FOR A MEGALOMANIAC!


HAVE YOU CONSIDERED ANGER MANAGEMENT?
I CHALLENGE YOU TO A RACE!
CARLA VERSUS MAELSTROM.
IF WE WIN, WE KEEP CARLA AND THE JUNKYARD STAYS OPEN!


DRAT! I HAVE A WEAKNESS FOR CHALLENGES...
...I ACCEPT!


NICE WORK, HANNAH!
SO WHAT'S THE PLAN?
I DON'T HAVE A PLAN.
...I DON'T HAVE A PLAN.
I DON'T BELIEVE IN PLANS. ONLY FATE.


...PLEASE TELL ME YOU HAVE A PLAN?



In order to plan a successful path through the course, Carla will need to choose between many possible trajectories. If she chooses trajectories with too much lateral (sideways) acceleration, she may slide off the track. Help Carla find the best trajectory by eliminating turns that are too sharp for her speed!

The equation for lateral acceleration (side to side acceleration) is given below.

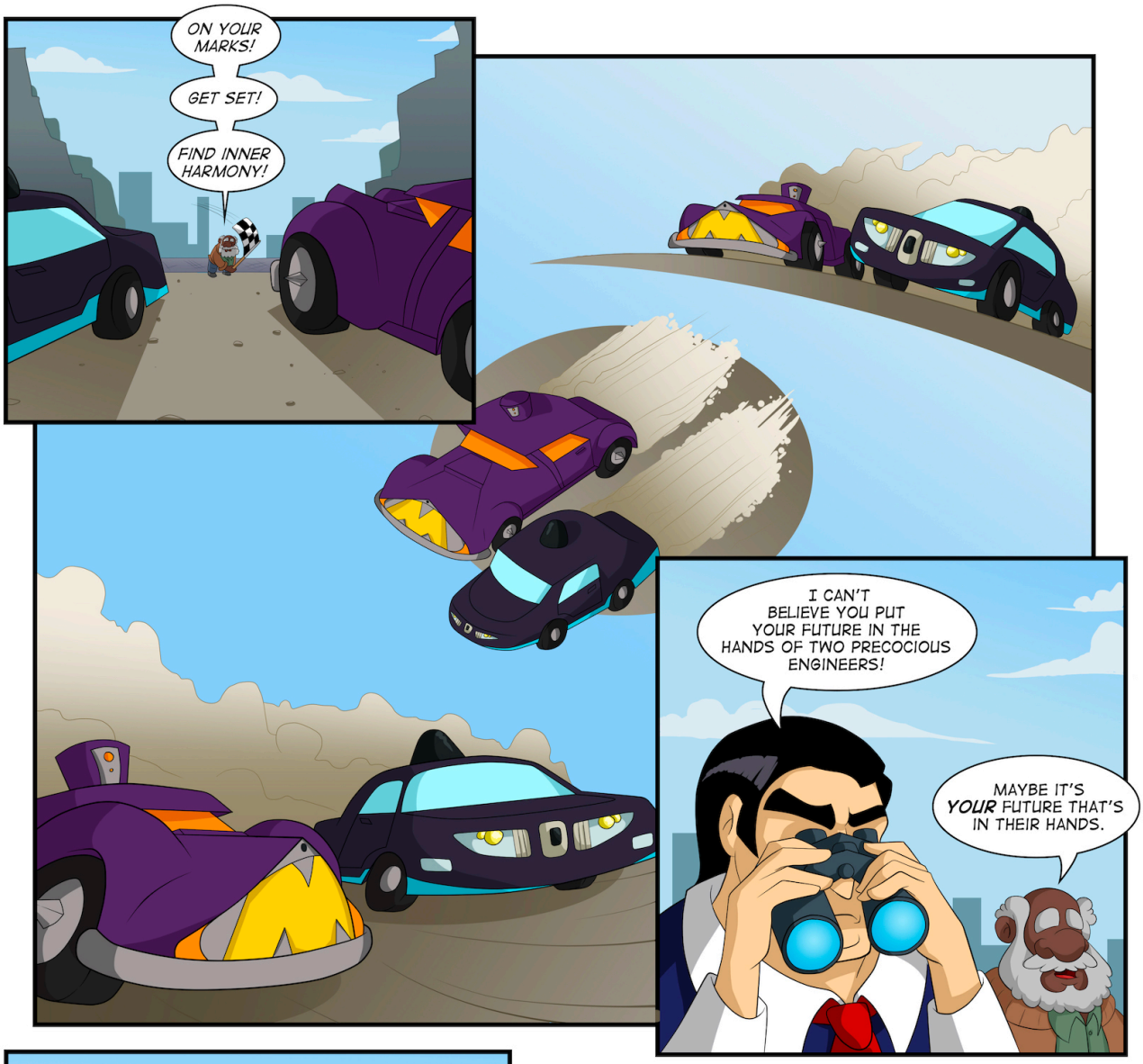
$a_{\text{lat}} = \frac{v^2}{R}$

In junkyard conditions, the **maximum** lateral acceleration that Carla's tires can support is $12 m/s^2$. If she's traveling at a velocity of $30 m/s$, what's the sharpest turn (**minimum** turning radius) she can make?

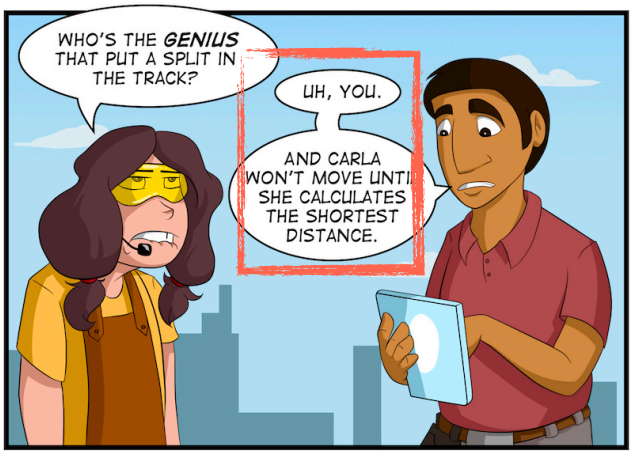
QUIZ QUESTION

What's the radius of the sharpest turn Carla can make?

- 50m
- 31.4m
- ✓ 75m
- 16m


ON YOUR MARKS!
GET SET!
FIND INNER HARMONY!
I CAN'T BELIEVE YOU PUT YOUR FUTURE IN THE HANDS OF TWO PRECOCIOUS ENGINEERS!
MAYBE IT'S YOUR FUTURE THAT'S IN THEIR HANDS.


SCREEEEEEEEEEEECH
DON'T STOP, CARLA!
YOU'RE WINNING!


WHO'S THE GENIUS THAT PUT A SPLIT IN THE TRACK?
UH, YOU.
AND CARLA WON'T MOVE UNTIL SHE CALCULATES THE SHORTEST DISTANCE.

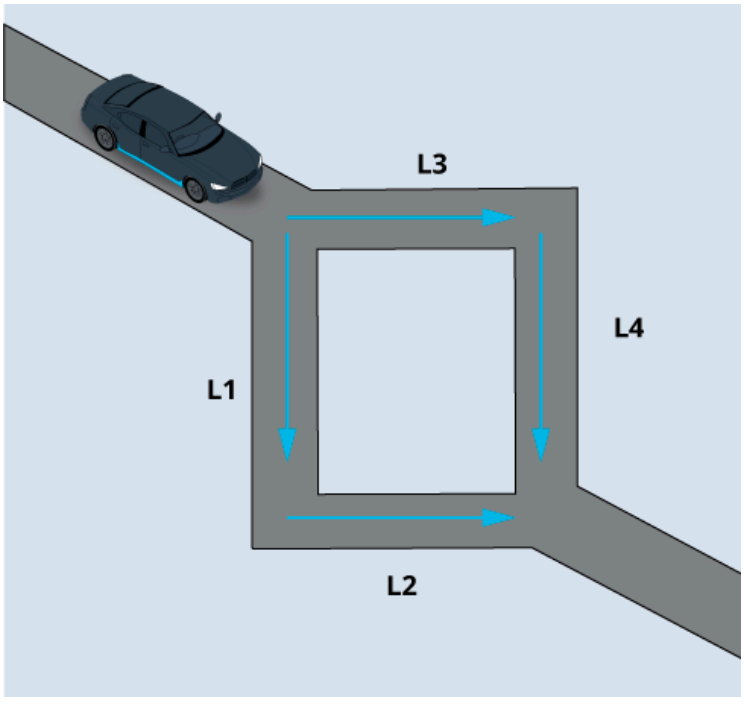

YOU'RE GOING TO HAVE TO HELP CARLA FIGURE THIS ONE OUT.

Carla's at a fork in the road and she insists on making the **optimal** choice for which way to go. This is a classic example of a **search** problem. In this situation, the optimal path is the **shortest** path.

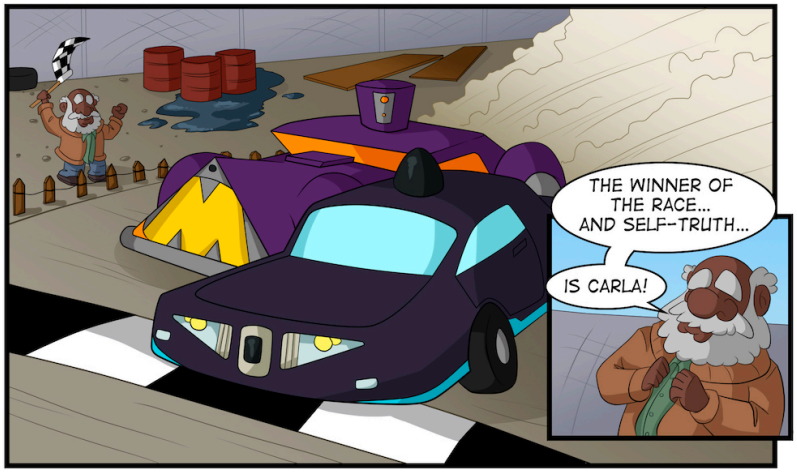
Carla has two choices:

1. Go Left - in which case she will travel a total distance of `L3 + L4`.
2. Go Right - in which case she will travel a total distance of `L1 + L2`.

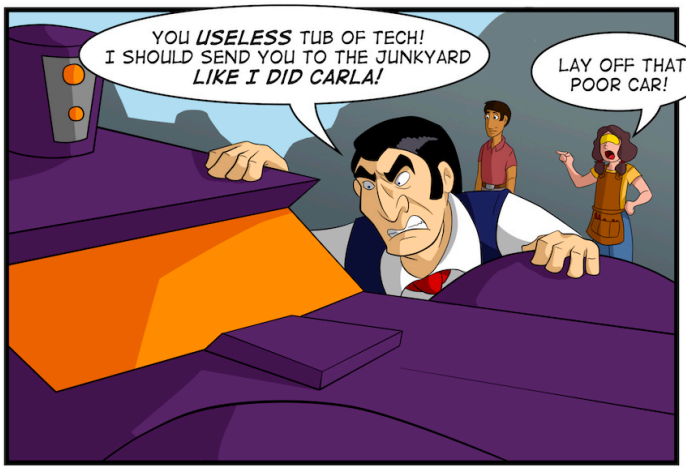
Complete the function below so that it returns the string `L` when option 1 is a shorter distance and returns the string `R` when option 2 is shorter. If the two options are the same it can return either `L` or `R`.

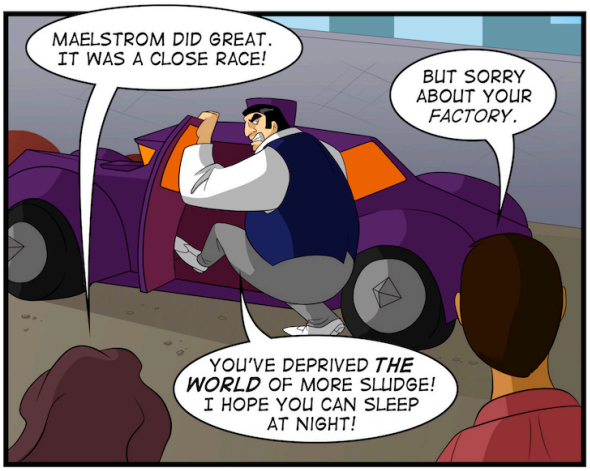


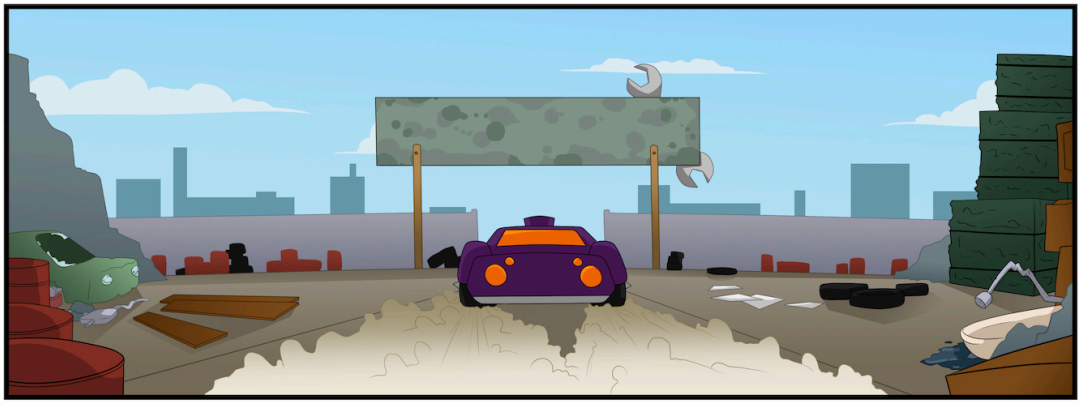
```python
# Right now the make_decision function ALWAYS decides to go left.
# Modify this function so it behaves appropriately.

def make_decision(L1, L2, L3, L4):
    if L1 + L2 <= L3 + L4:
        return "R"
    else:
        return "L"


###########################################################
#
# The code below is similar to the code that Udacity
# will use to test the correctness of your submission.
# You don't need to modify it but it may
# be helpful to look at for Python syntax help
#
def test_make_decision():
    # start by initializing this to 0
    number_correct = 0

    # TEST 1, should return "R" since right path has
    # length 5 which is < left path with length 8
    length_1 = 2
    length_2 = 3
    length_3 = 4
    length_4 = 4

    decision = make_decision(length_1, length_2, length_3, length_4)

    if decision == "R":
        # Test 1 passes
        number_correct = number_correct + 1

    # TEST 2, should return "L" since right path still
    # has length 5 but left is only 3.
    length_3 = 1
    length_4 = 2

    decision = make_decision(length_1, length_2, length_3, length_4)
    if decision == "L":
        # Test 2 passes
        number_correct = number_correct + 1

    if number_correct == 2:
        all_correct = True
    else:
        all_correct = False

    return all_correct

if test_make_decision():

if test_make_decision():
    print("Nice work! Your function passed both test cases.")
else:
    print("Not quite. Your function didn't pass both test cases.")

```

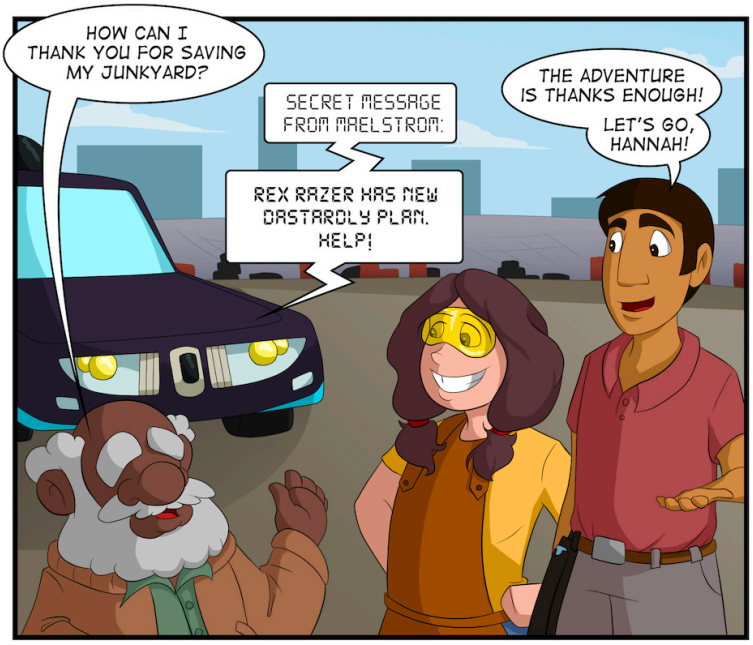

THE WINNER OF THE RACE... AND SELF-TRUTH...
IS CARLA!


WE WON!
IT'S LIKE WE KNEW WHAT WE WERE DOING!


YOU USELESS TUB OF TECH! I SHOULD SEND YOU TO THE JUNKYARD LIKE I DID CARLA!
LAY OFF THAT POOR CAR!

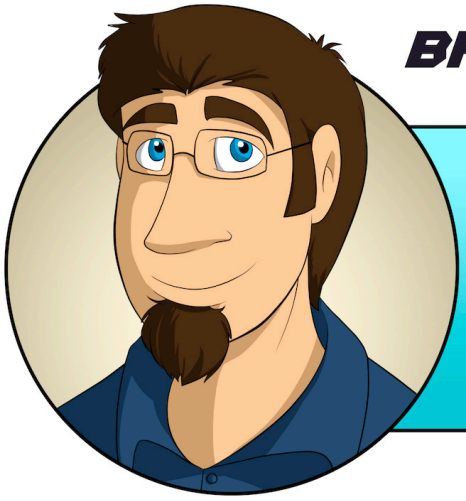

MAELSTROM DID GREAT. IT WAS A CLOSE RACE!
BUT SORRY ABOUT YOUR FACTORY.
YOU'VE DEPRIVED THE WORLD OF MORE SLUDGE! I HOPE YOU CAN SLEEP AT NIGHT!




HOW CAN I THANK YOU FOR SAVING MY JUNKYARD?
SECRET MESSAGE FROM MAELSTROM:
REX RAZER HAS NEW DASTARDLY PLAN. HELP!
THE ADVENTURE IS THANKS ENOUGH!
LET'S GO, HANNAH!


ONE JOURNEY ENDS.
ANOTHER BEGINS.
THE END?

BROUGHT TO YOU BY...



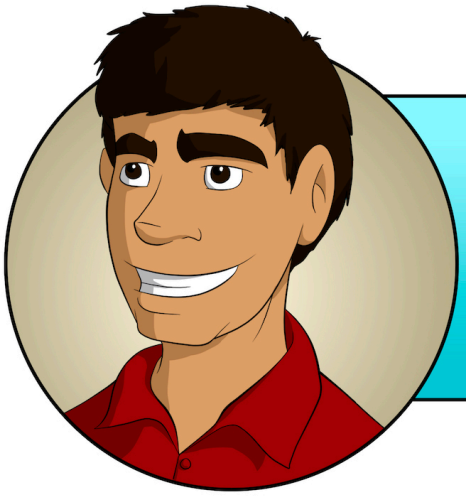
BEN TROWELL

-RANDOM ARTIST.
-GUMMI BEAR CONNOISSEUR.
-RUBBER DUCK ENTHUSIAST.

LinkedIn BEN TROWELL

MARTIN EDWARDS

CURRENT STATUS: FREELANCE WRITER.
FAVORITE THINGS: RENOVATING OLD HOUSES.
TRANSIT SYSTEMS: A GOOD CUP OF TEA.
SECRET PROJECT: FIND A DOG WHO GETS ALONG WITH CATS.



ANTHONY NAVARRO

PRODUCT LEAD AT UDACITY WITH A LOVE FOR TECHNOLOGY, ROBOTICS, AND SPACE.

LinkedIn ANTHONY NAVARRO
@AVNAVARRO42

ANDY BROWN

CURRICULUM LEAD AT UDACITY SINCE 2012 WITH A PASSION FOR LEARNING AND EDUCATION.