Physics 100 **Name:** _____
How Things Work
Midterm
Due April 20, 2022

This exam contains 9 pages (including this cover page) and 8 questions. The exam is graded out of 100 points. The questions have multiple parts, so make sure to answer everything!

Feel free to use any resources you want (class notes, the textbook, the practice problems that accompany the textbook, old homeworks). Just like the homework, answers do not require tons and tons of explanation. A couple sentences for each part of the question is probably fine, but try to use concepts from class in your answers. Pictures and graphs are sometimes helpful to illustrate what you're talking about. You can write your answers on the test or on a separate sheet of paper as long as you make it clear where I can find them!

Lastly, please write your signature on the bottom of this page to indicate that you agree to the following statement: "I affirm that I will not give or receive any unauthorized help on this exam, and that all work will be my own."

Grade Table

Question	Points	Score
1	10	
2	10	
3	10	
4	10	
5	15	
6	15	
7	15	
8	15	
Total:	100	

1. (10 points) **Falling in a pile of leaves**

It's a sunny autumn day and you've decided to go clean up the leaves covering your lawn. After many hours of raking, you've amassed a gigantic pile of leaves. Perfect for jumping!

You grab a ladder from the garage and climb up to the roof of your house. After taking a running leap off the roof, you fall about 20 feet and land safely in the leaves below.

(a) (5 points) Explain using the concepts of acceleration and force why falling into the leaves allows you to land safely.

(b) (3 points) You had so much fun the first time that you go up to the roof and jump off again, except this time you miss the leaves and land on your concrete driveway. Do you think this fall hurt more or less than when you hit the leaves? Why? Again, use acceleration and force in your answer.

(c) (2 points) Relate your answer in parts (a) and (b) to the way that airbags work in a car. Why do airbags help save your life in a car accident?

2. (10 points) **Stress-Strain Curve for Hi-Chews**

You're sitting around chewing on your favorite flavor of Hi-Chew candy when you suddenly have a desire to do some physics work. Inspired by the fresh fruit flavor of your Hi-Chew, you decide to answer the following questions:

(a) (3 points) Describe the material properties of Hi-Chews.

- Are they hard or soft (i.e. are they difficult to bend or not)?
- Are they strong or weak (i.e. does it take a lot of force to break a Hi-Chew in half or not)?
- Are they brittle or ductile (i.e. will a Hi-Chew snap before it bends or can you bend a Hi-Chew so that it isn't broken but has deformed in a way that it won't go back to its original shape)?

(b) (6 points) Draw a stress-strain curve for a Hi-Chew based on your description above.

(c) (1 point) What is the best flavor of Hi-Chew and why?

3. (10 points) **Dropping a golf ball on the pavement**

You're about to tee off at the first hole of your private country club when you accidentally drop your ball on the cart path.

You note how the ball falls, hits the pavement, and then bounces back up into the air. Being a physicist, you think, "Wait! If the ball changed directions when it hit the ground, it must have been accelerated! And if it was accelerated, that means a force must have acted on it!"

You go back to your notes from Dr. V's "How Thing Work" class to investigate your observation further.

(a) (4 points) What was the force that the ground exerted on the ball in order to make it change directions and go back up in the air?

(b) (4 points) Describe what is happening at a molecular level when the ball hits the ground and bounces back up. (Basically, at a molecular level, where does the force from part (a) come from?) Some pictures might help!

(c) (2 points) Which force is larger: the force of the ground on the ball or the ball on the ground, or are they the same? Explain your choice.

4. (10 points) **Leather pants in my new Ferrari**

On his way to Attica to teach his How Things Work class, Dr. V takes a left turn a little too fast. He's not wearing his seatbelt in order to avoid wrinkling his skin-tight leopard-skin pants. Unfortunately, the leopard-skin leather pants have very little friction against the imported leather interior of his brand new Ferrari, so he ends up sliding out of his seat and into the passenger's seat while the car goes around the turn.

(a) (4 points) Describe why when Dr. V takes the hard left turn, he feels like he's sliding to the right and ultimately ends up in the passenger's seat.

(b) (4 points) What force between the wheels and the pavement allows the car to make the turn?

(c) (2 points) What are some things that Dr. V could have done differently in order to keep from getting thrown into the passenger's seat? There are lots of answers to this, so just give one or two!

5. (15 points) **Spinning circus plates**

If you ever go to a circus or carnival you might see a "plate spinner," a performer who balances plates, bowls, and other flat objects on sticks without them falling off (see the picture below). Plate spinners balance the plates on the sticks by... well... spinning them!

If you're having trouble visualizing what this looks like, imagine spinning a basketball on your finger - it's basically the same thing. The performer puts a plate on the stick and quickly gets it rotating before letting go and watching it balance.

(a) (5 points) Explain why spinning the plates allows the performer to balance them on the narrow stick, and predict what you think would happen if the performer tried to balance the plate without starting it spinning first.

(b) (5 points) Why does choosing a thin stick to balance the plate on allow the plate to spin for a long time, as compared to a fatter stick with more contact area between the stick and plate?

(c) (3 points) Assuming that they are spinning at the same angular velocity and are the same diameter, which would have more angular momentum: a plastic plate, a real ceramic plate, or a ceramic bowl? Why?

(d) (2 points) Given your answer to part (c), which plates/bowls do you think would be easiest to keep balanced on the stick?

6. (15 points) **Car accidents!**

You're standing on a bridge looking at the serene river below when all of a sudden you see a speeding car go flying off the road nearby. Oh no!

(a) (5 points) Assume that the car is sealed airtight. If no water is able to get into the car, it will actually float despite being quite heavy. Why is this the case?

(b) (5 points) The driver breaks open his window in order to get out of the car and water starts to rush in. The car now begins to sink. Why does this happen?

(c) (3 points) Lastly, consider a more realistic situation in which the car is not assumed to be airtight, so that the water begins to slowly fill the car when it first hits the water. This time, rather than busting out of the car, the driver decides to conduct an experiment. He straps on his scuba gear that was conveniently located in his backseat so he can stay in the car as it fills with water. He wants to see if he can open his door underwater.
Say the car becomes fully submerged in the river and sinks to the bottom while the interior is only partially filled with water. The driver tries to open the door but can't! Why not?

(d) (2 points) The scuba diving driver patiently waits for more water to flow into the car before trying to open the door again. When will it be easiest for him to open the door to escape, and why?

7. (15 points) **Optimizing 0 to 60 speed**

People like fast cars. As such, car companies try really hard to minimize the time it takes for their vehicles to go from zero to 60 miles per hour. Due to your tremendous knowledge of physics, BMW has hired you as a consultant to figure out how to get their new car to go from zero to 60 as fast as possible. You arrive at the racetrack and the brand new BMW is stopped at the starting line on a long straight road when the light turns green. The car hasn't been modified in any way so far.

(a) (3 points) In order to accelerate most quickly, the driver tries to stomp on the gas pedal. Why is this not likely to be the best way to accelerate? Use a graph of applied force vs. friction force in your answer.

(b) (3 points) In order too allow the driver to press harder on the accelerator, you recommend putting softer tires on the car that grip the road better. Explain why using your graph of applied force vs friction.

(c) (3 points) BMW informs you that they plan to take many heavy parts out of the car in order to reduce its mass. You agree that removing weight will allow the car to accelerate more quickly, since less mass means it's easier to get the car moving. However, you warn BMW about taking *too much* weight away and tell them that if the car is too light the car will likely spin its wheels at the start line. Explain why is this the case.

(d) (3 points) If the car is rear-wheel drive, would it be better for BMW to place the engine in the back of the car or the front of the car to optimize acceleration?

(e) (3 points) Can you come up with some other creative ways for BMW to try and change their car to get its 0-60 time lower? Consider things like the engine, tires, or aerodynamics. There are lots of answers!

8. (15 points) **Removing a tablecloth from a table**

Perhaps at some point you've seen a magician pull a tablecloth out from underneath all the plates and silverware on a dinner table by pulling the tablecloth so quickly that nothing moves. Maybe you've even tried it yourself. Or maybe you've seen the original Ghostbusters in which Bill Murray tries and fails to pull off this feat, instead breaking most of the plates and glasses on the table, although "the flowers are still standing."

(a) (7 points) There are several ways to explain why you can rip the tablecloth out from under all the stuff on the table. First, explain using Newton's First Law how this trick works.

(b) (4 points) Another way to see how this trick works is by considering friction. Think about the force of friction between the tablecloth and a glass on top of it. If you pull slowly on the tablecloth like Bill Murray does in Ghostbusters, the glass moves along with the tablecloth as it moves. In this case, is the friction between the glass and tablecloth static or kinetic? Why?

(c) (4 points) The slow pull in part (b) is bad, since the glass will fall when it reaches the edge of the table! If instead you pull the tablecloth really hard, you're applying a big force to it, as well as the glass sitting on top of it. Explain using friction why the big force allows the tablecloth to move from under the glass without dragging it along.