Physics 211 Quiz 2

Instructions for this quiz:

This quiz has three full questions and one short one, totaling 100 points. It begins at 11:00 and runs until the end of class. You may have an extra ten minute grace period to scan and submit your work; if for any reason you are not able to submit your work by 12:30, please contact Walter or Mario.

Exception: Students who receive an extra-time accommodation through the Center for Disability Resources may take that extra time. If you receive 1.5× time for the quiz, you should complete your work by 1:00 and submit by 1:10; if you receive double time, you should complete it by 1:40 and submit by 1:50. If this timetable does not work for you or you require additional accommodations, please contact Walter or Mario. We will work out arrangements with you.

- **You must show your reasoning to receive credit**. Where appropriate you should make use of words and diagrams, alongside equations and numbers, to show your reasoning.
- You may use $g = 10\,\mathrm{m/s^2}$ throughout to minimize arithmetic.

You may either:

- Write on this document electronically, using a stylus and tablet
- Print this document out and write on it, and submit scans or photographs of it
- Write the answers on your own paper, and submit scans or photographs of it

If you submit scans or photographs, please ensure that you are submitting JPEG or PDF files. Do not submit "Live Photos" (from newer iOS devices) or .HEIC files.

You may:

- Consult any materials on the course website, YouTube channel, any of your notes, or the OpenStax textbook for reference
- Contact teaching staff to ask for clarification on any portion of the exam. (We will try to provide quick responses to emails and monitor Blackboard Collaborate and Discord during this time for your questions. Proctors will also be monitoring Blackboard Collaborate for questions.)
- Use a graphing calculator to do arithmetic or graph functions
- Make use of Google Calculator, Desmos, or similar tools to do arithmetic or graph functions
- Use a translation tool or dictionary to translate anything to your native language

You may not:

- Provide assistance to anyone else in our class on this quiz while they are taking it
- Seek assistance from anyone other than teaching staff on this quiz while you are taking it
- Use a computer program or calculator to do algebra for you
- Consult online references outside the class other than the OpenStax textbook (for example, Chegg and Coursehero) regarding the material on the quiz after the quiz period begins

Regardless of format, please copy the following text below, or write it in your submission, and sign your name to it:

"I affirm that my answers represent my own work and understanding, and that I have not given or received unauthorized help on this quiz."

Question 1

A Formula 1 car; note the "reverse wing" on the back.

In Formula One automobile racing, people drive specially-designed cars around tracks with tight turns at high speeds. These cars have a shape designed to push up on the air as it goes by. At high speed, this design creates an extra aerodynamic force pushing down on the car. Formula One drivers call this "downforce"; we will use the symbol D for it. For this problem, you may neglect *drag* (the aerodynamic force pointing backward), but you should include the downforce D pushing downward.

In the race track in Istanbul Park, there is a sharp leftward turn that approximates a semicircle with a radius of $r = 100$ meters. Suppose that the road is flat in this curve, the coefficient of static friction between racing tires and the pavement is $\mu_s = 0.8$, and that the car has a mass of $m = 600$ kg.

(The pink arc shown is a segment of a circle with a radius around $r = 100$ m, following roughly the path around the track.)

a) Draw a force diagram for the car as it makes its way around this curve. It will be easiest if you draw this diagram from a perspective looking at the rear of the car. (5 points)

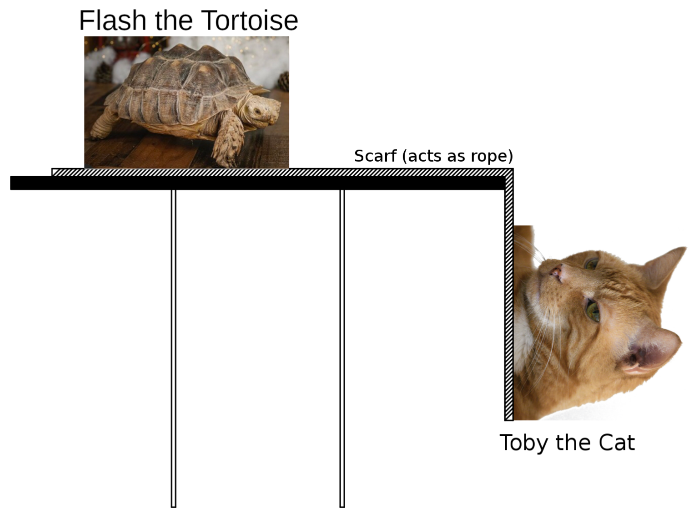
b) Very fast drivers have traveled around this curve at $v = 75$ m/s. Determine the downforce D required to do this. (You may give an answer either in newtons, or in terms of m, g, μ, r, and v.) (15 points)

c) Drivers going around this curve feel their heads being pulled very strongly to the right, and must do special exercises to strengthen their neck muscles to exert a force to the left in order to keep their heads straight. What force is pulling them to the right? If there is no such force, explain why the driver's neck must apply such a strong force to the left to their head in order to keep their head straight. (10 points)

Question 2

Flash the Tortoise isn't quite so fast as a race car. Flash is sleeping on a scarf sitting on a table, with one end hanging off of the other side. Since the scarf is so light, the only place there is friction is underneath Flash.

Toby the Physics Cat sees the other end of the scarf hanging over the edge of the table; she jumps up and grabs it, and her weight begins to pull Flash and the scarf off the table. (You may assume that the scarf doesn't stretch and has negligible mass.)



Flash has a mass m_F; Toby has a mass m_T. The coefficient of kinetic friction between the scarf and the table is μ_k; since the scarf is so light, the only place where there is friction is underneath Flash.

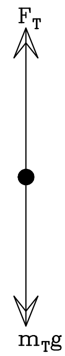
I would like to find the acceleration of the two animals and the scarf.

On the next page, you'll find my solution, but my solution contains an error. On the following page, I will ask you a few questions about my work, and ask you to fix my mistake.

Since this problem asks us to connect the forces on objects to their acceleration, I will use Newton's second law $\vec{F} = m\vec{a}$. First I write force diagrams for the two objects, and write down Newton's second law in each direction that matters for each object. I choose a conventional coordinate system where the positive $x-$axis is to the right and the positive $y-$axis is up.

Note that F_T is the force of tension, but m_T is Toby's mass.

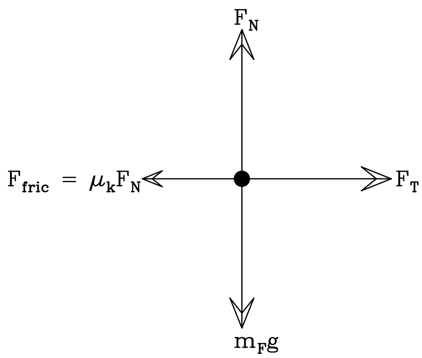
Toby:



$$Y : F_T - m_T g = m_T a \tag{1}$$

(Nothing happens in X for Toby)

Flash:



$$Y : F_N - m_Q g = 0 \tag{2}$$

(since the acceleration in y is zero)

$$X : F_T - \mu_k F_N = m_F a \tag{3}$$

Since the scarf doesn't stretch, I've used the same acceleration variable for the two animals, since their accelerations must be the same.

We now solve this system of equations by substitution. Solve equation (1) for the tension force and solve equation (2) for the normal force; this gives

$$F_T = m_T g + m_T a \tag{4}$$

$$F_N = m_F g \tag{5}$$

Substitute the results from (4) and (5) into (3), and solve for a:

$$m_T g + m_T a - \mu_k m_F g = m_F a \tag{6}$$

$$m_T g - \mu_k m_F g = (m_F - m_T) a \tag{7}$$

$$\frac{m_T g - \mu_k m_F g}{m_F - m_T} = a \tag{8}$$

... which is what we were supposed to find.

Remember, your job is to find the error that I have made and fix it.

Question 2, continued

a) The solution I got for the acceleration of the animals is

$$a = \frac{m_T g - \mu_k m_F g}{m_F - m_T}.$$

Right away, something about the mathematical form of this solution should tell you that there is a mistake. What about this answer should make you skeptical? (10 points)

b) What mistake did I make? You can describe it briefly here, or indicate it clearly on the previous page. (10 points)

c) What should the answer be instead? Correct my work on the previous page or below, and tell me what the acceleration should be instead. (10 points)

Question 3

Latte, Alicia's horse, is trying to pull a sleigh[a] up a snow-covered hill, sloping upward with an angle of $\theta = 10°$. Suppose Latte has a mass $m_L = 400$ kg. The coefficient of static friction between her hooves and the ground is $\mu_s = 0.5$; the coefficient of kinetic friction between the sleigh and the snow is $\mu_k = 0.1$. The rope connecting her harness to the sleigh is parallel with the surface of the hill.

Latte wants to pull the sleigh up the hill at a constant speed. In this problem, you will determine the most massive sleigh that she can pull. You may give your answers either numerically or in terms of g, m_L, μ_k, μ_s, and θ.

[a] A sleigh is a vehicle with a smooth bottom designed to slide over snow or ice with minimal friction.

a) Draw a force diagram for Latte and a force diagram for the sleigh. Indicate your choice of coordinate system by your diagrams (i.e. which way is x and which way is y?) (5 points)

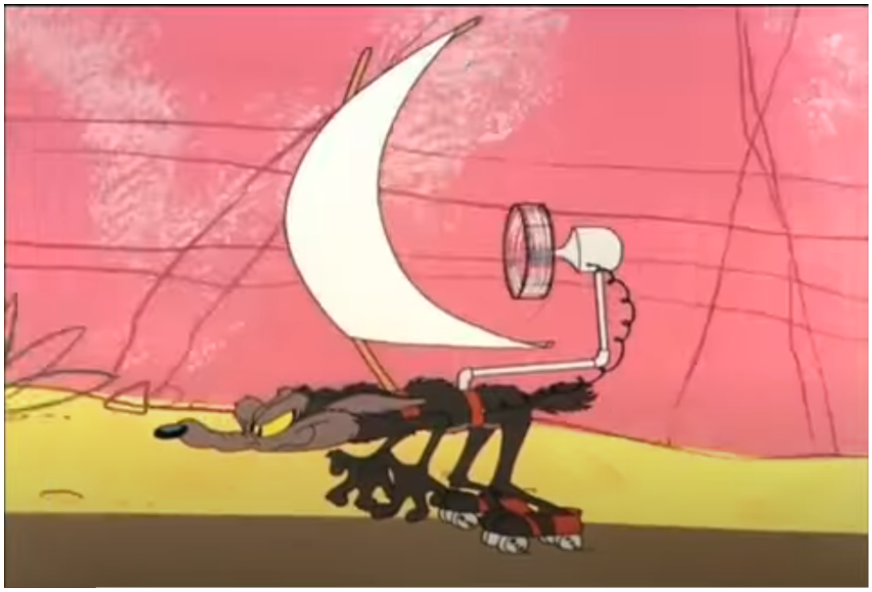
b) Write down expressions of Newton's second law for the sleigh and for Latte. (5 points)

c) Suppose that Latte is strong enough that her ability to pull things is limited by traction, not by her strength. Solve the system of equations you obtained in (b) to determine how massive of a sleigh she can pull up the hill. (10 points)

d) What is the tension in the rope as she is doing so? (10 points)

Question 4

In an old American cartoon, the character Wile E. Coyote builds a machine with a sail and a fan to help him go faster. This is shown as working like a sailboat, but better, in that the fan provides a strong wind to push on the sail.



Would this machine work? Explain why or why not, and refer to the forces applied to the various parts of the machine and to the wind in your explanation. (10 points)