Physics 211 Practice Exam 3

Question 1

Finn is a water-loving and very strong dog who has gotten good at jumping off of a boat to catch a Frisbee floating in the water. He's got a mass of $m = 25$ kg. When he jumps, his muscles are able to produce 450 J of energy. For simplicity, let's think about Finn jumping horizontally from the side of a boat, just so we don't have to do any trigonometry. You may approximate Finn as a single point, even though that's not quite realistic.

a) Suppose that Finn jumps horizontally from a very massive boat (so massive that it will not move) as fast as he can from a height of $h = 1$ meter. What velocity v_0 will Finn have once he jumps? *(5 points)*

b) If this boat is floating 2.5 m away from a Frisbee in the water, will Finn be able to jump on top of it?*(5 points)*

c) Now, suppose that Finn jumps horizontally from a much lighter canoe with the same mass as Finn (25 kg), also from a height of $h = 1$ meter. (The canoe is floating in the water, and is free to move.) Recall that Finn's muscles can only produce $E = 450$ J of energy in a jump, which must be shared between the canoe and Finn.

Determine the velocities of Finn and the canoe after he jumps. *(8 points)*

d) If this canoe is floating 2.5 m away from the same Frisbee, and Finn is again jumping from a height of $h = 1$ m, will Finn be able to jump on top of his Frisbee? *(7 points)*

Question 2

A rugby player with a mass of $M = 80$ kg is running 45 degrees east of north at a speed of 5 m/s. They are tackled by another player running 60 degrees west of north at a speed of 6 m/s. After the impact, the two players are moving directly north.

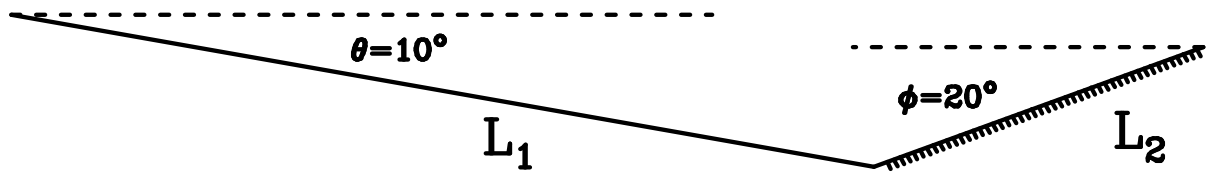
a) What is the mass of the second player? *(15 points)*

b) How fast are they moving after the impact? *(10 points)*

Question 3

Heavy trucks driving down steep mountains must continually apply their brakes to maintain a safe speed, as you saw in your homework.

If their brakes fail or overheat, these roads are equipped with "runaway truck ramps", which are short uphill pathways (made of sand or gravel) with a large coefficient of rolling friction. A truck whose brakes overheat can steer into the ramp and come safely to a stop. Suppose that a truck of mass m is driving down the hill at a speed v_0 when its brakes fail. It is a distance L_1 away from the ramp, traveling at a speed v_0. When it reaches the ramp, it exits the highway and heads up the ramp, traveling a distance L_2 before coming to rest. In this problem, you will calculate the distance L_2 in terms of μ_r, g, m, L_1, v_0, θ, and ϕ.



a) Write an expression for the total work done by gravity during the entire motion in terms of g, m, L_1, L_2, θ, and ϕ. *(10 points)*

Question 3, continued

b) Write an expression for the total work done by friction during the entire motion in terms of μ_r, g, m, L_2, and ϕ. (Note that the truck rolls without appreciable friction until it gets to the gravel-filled ramp, since its brakes have failed.) *(10 points)*

c) Write a statement of the work-energy theorem/conservation of energy in terms of μ_r, g, m, L_1, L_2, v_0, θ, and ϕ that you could solve for L_2. (You do not need to solve it.) *(10 points)*

d) While the truck is descending the steep $\theta = 10°$ hill, a small car is driving up the hill in the other lane while carrying a heavy load.

Suppose that car has an engine that can produce 75 kW of power. If the car wants to travel up the hill at 10 m/s (23 mph; 36 km/hr), what is the maximum mass that it can have? *(5 points)*

Question 4

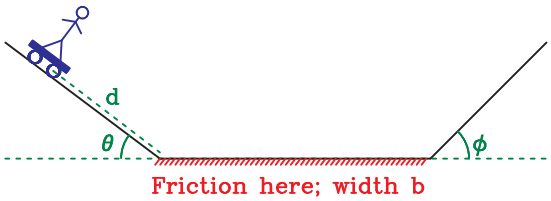
A firecracker of mass 1 kg is launched straight upward. When it is 200 meters above the ground and traveling upward at a velocity of 50 m/s, it explodes, separating into two pieces. After the explosion, one piece has a mass of 600 grams and travels horizontally East at 40 m/s.

a) What is the velocity of the other piece? (Remember, velocity is a vector.) *(15 points)*

b) What is the maximum height above the ground that this other piece will achieve? *(10 points)*

Question 5

A skateboarder of mass m is standing on the edge of a drainage channel, as shown. The left side, where the skateboarder starts, is elevated at an angle θ; the right side is elevated at an angle ϕ. The slopes on either side are smooth, and the skateboard moves over them with essentially no friction, but the flat bottom of width b is covered with a little sand, and the skateboard experiences a small amount of rolling friction there, with μ_r known.



The skateboarder starts a distance d up the left-hand side. They roll down the left side, across the sand-filled bottom, and up the right side.

(*Give your answers to the first two parts in terms of the variables above, along with g.*)

a) Determine the maximum distance d_2 that the skateboarder makes it up the right side. (This is the diagonal distance, not the height.) *(10 points)*

b) After rolling up and back down the right side, the skateboarder will come back to the left side. How far will they travel back up the left side? *(5 points)*

c) Suppose that you know numeric values as follows:

- $m = 75$ kg
- $\theta = 30°$
- $\phi = 40°$
- $\mu_r = 0.05$
- $d = 4$ m
- $b = 7$ m

How many times will the skateboarder travel across the sandy bottom of the channel before coming to rest? Explain the approach behind your solution fully. (There is an easy way and a hard way to do this; your group will get full credit for either!) *(10 points)*

Question 6

The dread pirate captain Piarrrrr Squared has some cannon on her ship. (She doesn't use them very much, since she prefers to throw π's at ships she's trying to capture.)

These cannon have a mass M; they launch cannonballs of mass m at a speed v horizontally. They are placed on a wooden deck; the coefficient of friction between the cannon and the deck is μ_k.

a) Explain in words why the cannon slide backwards when they are fired. (You don't need to do any mathematics here.) *(5 points)*

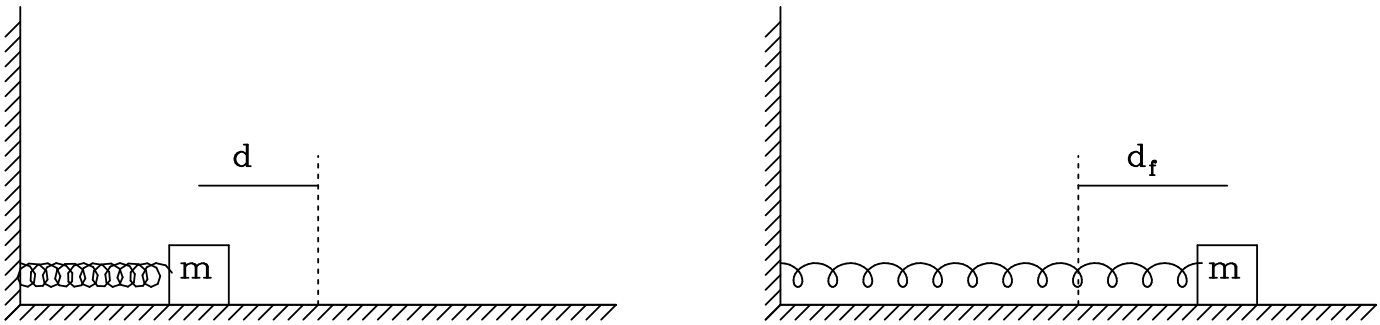
b) In terms of μ_k, m, M, v, and g, how far do the cannon slide backwards after they are fired before they come to rest? *(10 points)*

Piarrrrr's pirates get tired of pushing the cannon back to the edge of the ship after they are fired, so they get an idea: they'll mount some springs behind them that will stop them from sliding back so far and help push them back into position. (The cannon are placed at the equilibrium position of the springs, so that as soon as they begin to move backwards, the springs start to push them forwards again.)

Question 7

A spring has spring constant k. One end is fixed, and the other end is attached to a mass m, which is free to move horizontally along a table. The mass slides over the table with a coefficient of friction μ_k.

The spring is compressed a distance d from its equilibrium point and released. When the spring is released, it will push the mass to the right, until it reaches some other distance d_f past the equilibrium point.



a) How fast will the mass be traveling when it crosses the equilibrium point? Give your answer in terms of μ_k, d, m, and g. *(5 points)*

b) Write down an expression for the work done by friction as the block slides from its starting point to the final position d_f to the right of equilibrium. *(5 points)*

c) Write down an equation in terms of μ_k, d, m, and g that will let you solve for the distance d_f. You do not need to solve it. *(12 points)*

d) What algebraic technique would you have to use to solve this equation for d_f? *(3 points)*

Question 8

A clay block of mass M sits on top of a flat table. It sits on top of a hole in the table. It is struck from below by a fast-moving ball of mass m traveling at speed v_0 through the hole. The ball is not traveling straight up, though: its velocity is at an angle θ away from the vertical. The ball lodges in the clay block, and the block flies up in the air and lands back on the table.

In this problem, you will calculate where on the table the block lands.

a) Without doing any mathematics, outline a plan for figuring this out in words and diagrams. (You won't need this whole page.) *(8 points)*

b) Find how far away from the hole the block lands in terms of m, M, v_0, θ, and g.[1] *(17 points)*

[1] As a note, you can include other variables in your answer if you define them in terms of m, M, v_0, θ, and g. For instance, if you say "$u = ...$", where u is defined in terms of the given parameters, you can then use u in your answer. Depending on what you do, this might make your algebra a bit simpler.