Physics 211 Exam 2, Form B

Problem 1	Problem 2	Problem 3	Problem 4	Total
/25+10	/25	/25	/25	/100

Name: _____

Recitation section number: _____

- There are four questions worth a total of 100 points, with a possible 10 points extra credit.
- **You must show your reasoning to receive credit**. A numerical answer with no logic shown will be treated as no answer.
- You are highly encouraged to use both pictures and words to show your reasoning, not just algebra.
- If you run out of room, continue your work on the back of the page.
- Remember, show your reasoning as thoroughly as possible for partial credit.
- You may use $g = 10\,\mathrm{m/s^2}$ throughout, except where indicated, to minimize arithmetic.

Recitation Schedule

M003	8:25 - 9:20	Avinay	B129E
M011	8:25 - 9:20	Lindsay	106
M019	8:25 - 9:20	Francesco	HL205
M004	9:30 - 10:25	Avinay	B129E
M012	9:30 - 10:25	Julian	106
M020	9:30 - 10:25	Tie	Sims 437
M025	9:30 - 10:25	Francesco	HL205
M005	10:35 - 11:30	Avinay	B129E
M013	10:35 - 11:30	Lindsay	106
M021	10:35 - 11:30	Tie	Sims 437
M023	10:35 - 11:30	Francesco	HL205
M006	11:40 - 12:35	Andrew	B129E
M014	11:40 - 12:35	Lindsay	106
M022	11:40 - 12:35	Tie	Sims 437
M007	12:45 - 1:40	Andrew	B129E
M015	12:45 - 1:40	Kyle	106
M008	2:15 - 3:10	Andrew	B129E
M016	2:15 - 3:10	Harris	106
M009	3:45 - 4:40	Harris	B129E
M017	3:45 - 4:40	Kyle	106
M010	5:15 - 6:10	Harris	B129E
M018	5:15 - 6:10	Kyle	106

Question 1

The coefficient of kinetic friction between a table of mass $m = 100$ kg and the ground is $\mu_k = 0.6$. You would like to move this table by pushing on it. (You are not trying to make the table accelerate, only to make it continue to move at a constant speed.)

Calculate the minimum force required to make the table move under the following conditions. If *no* force, no matter how large, will move the table, then say so. Note that you will want to draw force diagrams as part of your solutions to each part.

a) You push on the table horizontally, parallel to the ground. (5 points)

b) You push on the table at an angle directed 20 degrees above the horizontal (that is, you are pushing sideways and upward.) (5 points)

Question 1, continued

c) You push on the table at an angle directed 20 degrees below the horizontal (that is, you are pushing sideways and downward.) (5 points)

d) You push on the table at an angle directed 60 degrees below the horizontal (that is, you are pushing a bit sideways, and mostly downward.) (5 points)

e) Explain in words why your answers to parts (b) and (c) are different. (5 points)

f) Find the direction that you should push in order to move the table with the minimum effort. (10 points extra credit. If you wish to attempt this part, you may want to save it for the end of the exam, to ensure you do not run out of time.)

Question 2

The dread pirate captain Piarrr Squared sails in a ship with a cannon mounted a height h above the waterline, pointed horizontally. The coefficient of kinetic friction between the cannon and the ship's wooden deck is μ_k; the cannon has mass M, and it fires cannonballs with mass m. When the cannon is fired, the cannonball exits the front of the cannon with velocity v_b (horizontally), flying through the air and splashing into the sea a distance d away from the base of the ship. The cannon recoils with a speed v_c, sliding backwards on the deck until it comes to rest a distance b.

In this problem, you will relate the recoil distance b to the range d.

a) Outline the different components of the motion, drawing relevant diagrams, and describing briefly what physics ideas you will use to understand each one on this page. (5 points)

Question 2, continued

b) What is the relation between the velocity v_b (the cannonball going forward out of the cannon) and v_c (the cannon recoiling backwards)? (5 points)

c) What is the relation between the cannonball's speed v_b and the distance d? (5 points)

d) What is the relation between the recoil speed v_c and the distance b that the cannon slides? (5 points)

e) Combining these components, what is the relationship between b and d? (You do not need to solve for one variable in terms of the other, just write an equation relating the two.) Your answer will also involve the things given in the problem: μ_k, M, m, and g. (5 points)

Question 3

A person ties a rock of mass m to a string and spins it in a vertical circle of radius r at angular velocity ω. The string has a maximum tension $\tilde{T}$; if it is exposed to more tension than that, it will break. Give all your answers in terms of m, r, ω, and $\tilde{T}$.

a) Draw a force diagram for the rock at the top of the circle and at the bottom. (5 points)

b) What is the acceleration of the rock at the top of the circle? What about the bottom? Give both magnitude and direction. (5 points)

c) At the top of the arc, the string is stretched taut. What force pushes the rock upward, stretching the string? If there is no such force, what stops the rock from falling at the top of the circle? (5 points)

Question 3, continued

d) As you might expect, there is a minimum angular velocity; if he tries to spin the rock more slowly than this, the rock will fall. Find this minimum angular velocity. (5 points)

e) If he tries to spin the rock too fast, however, the string will snap. Find this maximum angular velocity. (You will need to think about where in the circle the string will snap first.) (5 points)

Question 4

Kibeth the sled dog is trying to pull a sled up a snowy hill, sloped at an angle θ above the horizontal. She wishes to drag it at a constant velocity. She wears a harness that is connected to the sled by a rope; this rope runs parallel to the ground. (Kibeth and the sled are the same height.)

The coefficient of static friction between the dog's paws and the ground is $\mu_s = 0.5$; the bottom of the sled has been newly waxed, and it moves without friction. The dog has a mass of $m = 20$ kg, while the sled has a mass of $M = 40$ kg.

You may solve this problem either using the numbers given or in terms of μ_s, m, M, and g.

a) Draw a force diagram for Kibeth. What force does she use to propel herself up the slope? Indicate your choice of coordinate axes. (5 points)

b) Draw a force diagram for the sled. (5 points)

Question 4, continued

c) Write down statements of Newton's second law for both the dog and the sled. (5 points)

d) Find the largest angle θ that the hill can have before Kibeth is unable to pull the sled. Alternately, you can write a system of three equations and three unknowns which will allow you to solve for θ; if you do this, indicate which three variables you would solve for. (5 points)

e) Kibeth and her sled encounter a hill that is steeper than this; her paws are sliding on the snow trying to pull the load uphill. Her owner puts a 10 kg weight (a bag of snow, perhaps) on the dog's back. Why did she do this? Explain in words, possibly referencing your equations for part (d). (5 points)