Physics 211 Exam 1, Form A

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

Name: ______________________________

Recitation section number: ___________

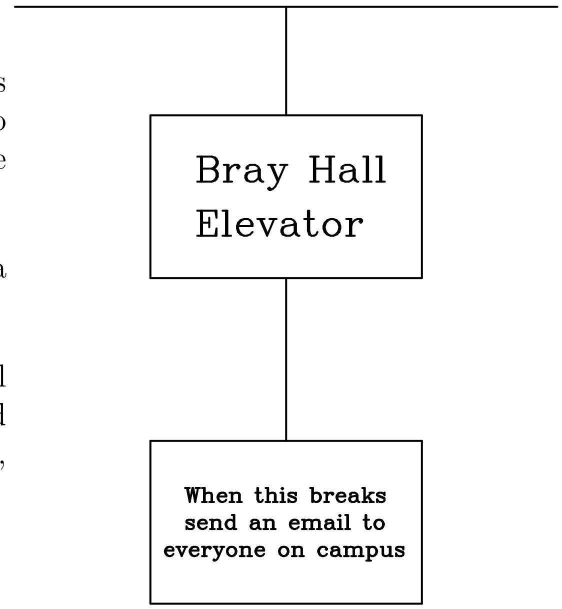
(see next page)

- There are four questions worth a total of 100 points.
- **You must show your reasoning to receive credit**. A numerical answer with no logic shown will be treated as no answer.
- You are encouraged to use both pictures and words to show your reasoning, not just algebra. Show your reasoning as thoroughly as possible for partial credit.
- If you run out of room, leave a note saying "see back page", and continue your work on the blank page at the end.
- Do not attempt to communicate with anyone other than teaching staff during the exam.
- You may use an ordinary scientific or graphing calculator, but not one that will do algebra for you. If you do not have a calculator, leave your answers in symbolic form.
- Other electronic devices (laptops, smartphones, smartwatches) are not allowed during the exam.
- You may use $g = 10\,\mathrm{m/s^2}$ throughout, except where indicated, to minimize arithmetic.
- Reference material and an extra sheet of paper is on the last page.

Recitation Schedule

M003	8:25-9:20	106	Chad
M016	8:25-9:20	208	Nada
M004	9:30-10:25	B129E	Chad
M013	9:30-10:25	106	JT
M017	9:30-10:25	208	Nada
M005	10:35-11:30	B129E	Patrick
M014	10:35-11:30	106	JT
M018	10:35-11:30	208	Adil
M006	11:40-12:35	B129E	Sierra
M015	11:40-12:35	106	Gentian
M019	11:40-12:35	208	Adil
M007	12:45-1:40	B129E	Sierra
M020	12:45-1:40	208	Manabputra
M021	12:45-1:40	Whitman 306	Gentian
M008	2:15-3:10	B129E	Gabriel
M022	2:15-3:10	Maxwell 110	Manabputra
M009	3:45-4:40	B129E	Gabriel
M010	5:15-6:10	B129E	Gentian
M011	5:15-6:10	104N	Patrick

Question 1



An elevator in Bray Hall has two signs that hang from strings from the ceiling, as shown here. The top sign is attached to the ceiling with a string; the bottom sign is attached to the top sign with a string.

Each sign has a mass of 2 kg, and the strings can apply a maximum tension force of 50 N before they break.

A person enters this elevator on the top floor of Bray Hall and rides it downward. The elevator accelerates downward at 3 m/s^2, moves at a constant velocity for a little while, then accelerates upward at 3 m/s^2 until it comes to a stop.

a) Draw force diagrams for each sign while the elevator is moving at a constant velocity. Will either string break during this stage of the motion? (*5 points)*

b) Draw force diagrams for each sign while the elevator is accelerating downward. Will either string break during this stage of the motion? (*10 points)*

c) Draw force diagrams for each sign while the elevator is accelerating upward. Will either string break during this stage of the motion? (*10 points)*

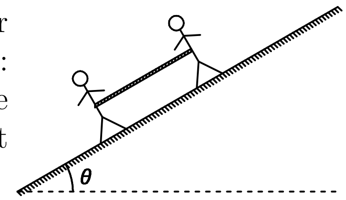
Question 2

Two Physics 211 students of equal mass m are good friends and go hiking together in an icy forest. Otto is wearing shoes without much traction; Eustace has on boots with better tread. The coefficients of friction between their shoes/boots and the ice are as follows:

	μ_s	μ_k
Otto	0.3	0.2
Eustace	0.5	0.4

a) What is the steepest slope that Otto can walk up without help? (They want to walk at constant speed.) *(10 points)*

The two of them now encounter a steeper slope that is too steep for Otto to climb, since he keeps slipping on the ice. Eustace has an idea: they tie a rope between them, so Eustace can help Otto climb. Eustace is in front, and Otto is behind him. As before, they want to travel at constant velocity: they're just trying to make it up the hill.

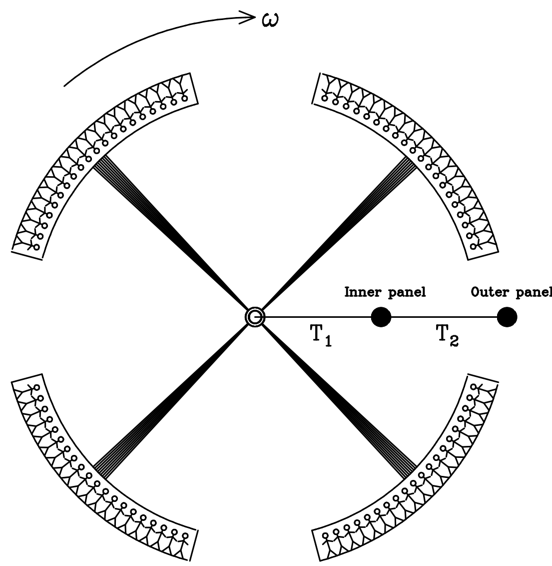


b) Draw force diagrams for Otto and for Eustace. *(5 points)*

c) Find the steepest slope they can climb by cooperating like this, and the tension in the rope connecting them while they are climbing such a slope. *(10 points)*

Question 3

Futurists and science-fiction authors have often imagined circular spacecraft with "artificial gravity", in which humans (or other things accustomed to gravity) occupy a ring-shaped habitat. The ring rotates around a central hub, creating the impression of gravity for its inhabitants. They feel heavy, objects that they drop fall to the floor, and they otherwise experience all of the same things that people on a planet do.



Imagine that such a ship has a radius of R and is in deep space, far from any planets or moons, where there is almost no (actual) gravity. Suppose that the crew of the ship wants the passengers to experience "artificial gravity" similar to that on Earth. (In an actual station R would be much larger than the height of people; this drawing is not to scale.)

a) Explain how this works. Why does a rotating circular spacecraft simulate gravity for its inhabitants? Specifically, what force presses them against the floor? If there is no such force, then explain why a person on such a spacecraft standing on a scale could see the same reading as they would on Earth, and why an object that they drop falls to the floor. *(8 points)*

b) At what rate must the spacecraft rotate so that the people aboard experience artificial gravity that feels equal to Earth's? Give your answer in terms of g and R.

This station is powered by solar panels of mass m connected by cables to the central hub. A cable of length $\frac{1}{2}R$ runs from the hub to the inner panel; a second cable runs from the inner panel to the outer panel. These solar panels also rotate along with the rest of the station at the same angular velocity.

c) Draw a force diagram for the inner solar panel and the outer solar panel. (Note that the tension in the two cables is different.) *(5 points)*

d) In terms of m, R, and ω, calculate the tension T_1 in the cable between the hub and the inner solar panel, and the tension T_2 in the cable between the inner solar panel and the outer solar panel. *(7 points)*

Question 4

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 push this table across the floor at a constant speed.

Calculate the minimum force required to keep the table moving across the floor at a constant speed under each of 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)*

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)*

Reference Material

Newton's second law says that

$$\sum \vec{F} = m\vec{a}.$$

Newton's third law says that if an object A applies a force on an object B, object B applies a force back on object A with the same magnitude in the opposite direction.

If an object travels in a circle with radius r, it must accelerate toward the center of the circle at

$$a_c = \omega^2 r = \frac{v^2}{r}.$$

The force of kinetic friction between two surfaces sliding past one another is

$$F_{kf} = \mu_k F_N$$

The force of static friction between two surfaces is at maximum

$$F_{sf} = \mu_s F_N$$
