Physics 211, Exam 2
(Alternate version)

Name: _____

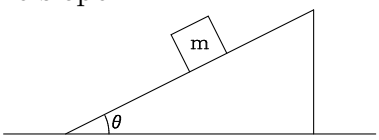
Recitation section number: _____

- There are four questions worth 25 points each.
- **You must show your reasoning to receive credit**. A numerical answer with no logic shown will be treated as no answer.
- 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.

Name: _____

Question 1

A book of mass m rests on a slope with angle of inclination θ as shown below. There is friction between the book and the slope.



a) Draw a force diagram for the book, indicating your choices for your coordinate axes. (5 points)

b) Suppose first that the book does not slide down the slope. In terms of θ, m, and g, compute the minimum value of μ_s required to make the book stay on the ramp without sliding. (Your answer may not depend on all three of these quantities.) (10 points)

c) Now, suppose that the book does slide down the slope. The coefficient of kinetic friction is μ_k. In terms of θ, μ_k, m, and g, compute the acceleration with which the book slides down the ramp. (Your answer may not depend on all four quantities.) (10 points)

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Question 2

The weight of a person standing on the surface of the Moon is one-sixth his weight on the surface of the Earth. Suppose the radius of the Moon r_M is exactly one-quarter that of the Earth.

a) As a fraction of the mass of the Earth, what is the mass of the Moon? (Note: You do not need numerical values for the masses and radii of the Earth and Moon.) *(10 points)*

b) The Moon orbits the Earth with a nearly constant speed in a nearly circular orbit. Is the Moon accelerating? If so, how do you know? What force causes this acceleration? (5 points)

c) The Moon orbits the Earth with angular velocity ω. In terms of the mass of the Earth m_E, the gravitational constant G, and ω, what is the distance from the Earth to the Moon? (10 points)

Name: _____

Question 3

In an exhibit at the NASA museum in Huntsville, AL, there is a "human centrifuge". Guests stand upright against the walls of a circular room with a radius of 8 meters which then spins at an angular velocity ω about an axis through its center. Then, once the room is spinning, the floor drops away from the guests' feet. They feel themselves pressed against the walls, but do not fall.

a) Draw a force diagram for the person in this exhibit. Make sure you label the axes in your force diagram to indicate which direction is "up", and which direction points toward the center of the circular room. (5 points)

b) Suppose the coefficient of static friction between the guests' clothing and the wall is 0.4. At what angular velocity ω must the room spin to ensure that the guests do not fall? (15 points)

c) Guests in this exhibit feel themselves "pressed against the walls", and find it very difficult to lift their arms away from the wall; for instance, it may require a force of 25 N to hold a one-kilogram object in place away from the wall. Is there a force pressing the guests and their hands against the wall? If so, what is that force? If not, how do you explain the difficulty lifting objects away from the wall? (5 points)

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Question 4

A book with a mass of 2 kg rests on a table; the coefficient of kinetic friction μ_k between them is 0.4. A string connects that book to another book hanging vertically off the side of the table with mass 3 kg; this hanging book is 140 cm above the ground. When the hanging book is released, it accelerates toward the ground, dragging the other book on the table with it.

a) Draw a force diagram for both books. Indicate your choice of signs for the $x-$ and $y-$axes on both diagrams; that is, which directions do you consider positive, and which do you consider negative? (5 points)

b) Are the accelerations of the two books related? If so, write a mathematical relationship between them. (5 points)

c) Calculate the accelerations of the books. (10 points)

d) How long will it take the hanging book to strike the floor? (5 points)

Reference Sheet

Centripetal acceleration of an object in uniform circular motion:

$$a_c = \frac{v_T^2}{r} \text{ or } \omega^2 r$$

Tangential velocity $v_T = \omega r$

Newton's law of universal gravitation: $F_g = \frac{Gm_1m_2}{r^2}$, where r is the distance between the centers of the objects

Newton's second law: $\vec{F} = m\vec{a}$
Newton's third law: $\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$

Kinematics of circular motion for an object traveling in a circle with radius r at angular velocity ω:

$$\begin{aligned} x(t) &= r\cos(\omega t) \\ y(t) &= r\sin(\omega t) \\ v_x(t) &= -\omega r\sin(\omega t) \\ v_y(t) &= -\omega r\cos(\omega t) \end{aligned}$$

Kinematics of constant acceleration:

$$\begin{aligned} x(t) &= \frac{1}{2}at^2 + v_0t + x_0 \\ v(t) &= at + v_0 \end{aligned}$$

Maximum force of static friction: $\mu_s F_N$
Force of kinetic friction: $\mu_s F_N$