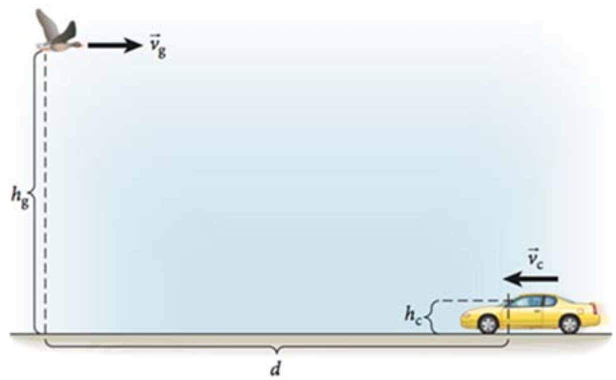
Spring 2018 Physics 7A Lec 001 (Yildiz) Midterm I

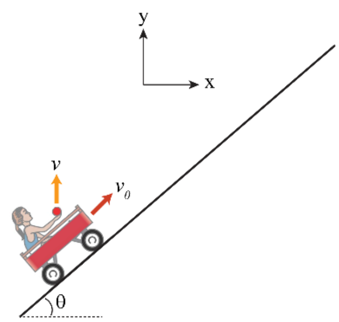
1. (20 points) Wild geese are known for their lack of manners. One goose is flying at a constant altitude h_g when it sees a car in the distance moving towards itself. The goose is flying at a speed of v_g and the car is moving at a speed of v_c relative to the ground. The center of the windshield is h_c off the ground.



a) The goose decides to poop on the windshield of the car. At what horizontal separation d between the goose and the windshield does the goose need to take action?

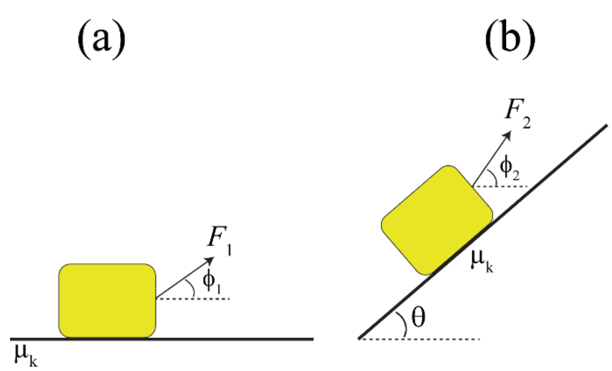
b) The driver sees what the goose is after and steps on the accelerator right when the goose is d away. If the distance between the windshield and the rear bumper of the car is l, what is the minimum (constant) acceleration of the car towards the goose so that the goose dropping misses the car entirely? [Neglect the shape of the car and assume it is h_c off the ground everywhere]

2. (20 points) A small cart is going up an inclined track with nothing pushing it, so it is decelerating. When the cart has instantaneous speed v_0, it fires a ball out of the cannon. The ball leaves the cart with speed v in a vertical direction *relative to the ground* (along the y axis, as shown in the figure). What should be the speed v of the ball (relative to the ground) in order for the ball to fall back to the cart? Express your answer in terms of v_0, g (gravitational acceleration), θ (the angle of the incline). Neglect friction and air resistance.



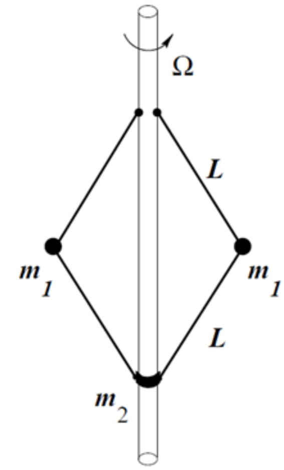
3. (20 points)

A suitcase of mass M is being pulled by a small strap across a level floor. The coefficient of kinetic friction between the suitcase and the floor is μ_k.



a. Find the optimal angle ϕ_1 of the strap above the horizontal to minimize the force necessary to pull the suitcase at constant speed. Find the minimum force F_1 required.
b. Now assume that the floor is tilted by angle θ relative to the ground. Find the optimal angle ϕ_2 of the strap above the horizontal.

4. (30 points)



Governor for a steam engine.

Early steam engines had a feedback device, called a governor, to automatically control the speed. The engine rotated a vertical shaft with an angular velocity Ω proportional to the engine's speed. On opposite sides of this shaft, two hinged rods each held a metal weight, which was attached to another such rod hinged to a sliding collar, as shown. As the shaft rotates faster, the balls move outwards, the collar rises and uncovers a hole, releasing some steam. Assume Ω is large enough that the figure is qualitatively accurate. Assume all hinges are frictionless, the rods are massless, each ball has mass m_1, and the collar has mass m_2. Find the equilibrium angle θ between the rods and the shaft as a function of the shaft angular velocity. (Assume Ω is large enough that the figure is qualitatively accurate.)

5. (20 points)

A mischievous child goes to an amusement park with his family. On one ride, after a severe scolding from his mother, he slips out of his seat and climbs to the top of the ride's structure, which is shaped like a cone with its axis vertical and its sloped sides making an angle θ with the horizontal as shown in the figure. This part of the structure rotates about the vertical central axis when the ride operates. The child sits on the sloped surface at a point d down the sloped side from the center of the cone and pouts. The coefficient of static friction between the child and the cone is μ_s.

a) What is be the minimum value of μ_s for the child to remain static when the ride is not operating?
b) The ride operator does not notice that the child has slipped away from his seat and so continues to operate the ride. What is the maximum angular velocity of the cone before the boy starts slipping?
c) Assume now that the cone is inclined upward (instead of downward as in the figure) with angle θ from the center of rotation and the child sits at a point d up the sloped side from the center of the cone. What is the maximum angular velocity of the cone before the boy starts slipping?

In b and c, express your answer in terms of μ_s, m, θ, g and d.