Physics 7A, Section 1 (Chiao)
1st Midterm
University of California at Berkeley

Wednesday, February 23, 2005, 6-8 pm, 1 Pimentel

IMPORTANT: Print your name, student ID number, GSI name, and your discussion section number on the front of your blue book.

This exam contains 6 questions, and will be graded out of a total of 100 points. You should answer all the questions to the best of your ability. You are allowed both sides of one sheet of **handwritten** notes, and the use of a calculator, but no QWERTY keyboards are allowed. Express all numerical results to 3 significant figures. A useful constant is the following: The acceleration due to Earth's gravity in the Bay Area is $g = 9.80$ m/s^2. All **boldface** letters indicate **vector** quantities.

Please show all your work in your blue book. Explain the steps in your reasoning in coherent, English sentences. Define all symbols that you use. If you do not show relevant work for any part of the problem, you will not be awarded any credit, even if the answer is correct. If you recognize that an answer does not make physical sense, and you do not have time to find your error, write that you know that the answer cannot be correct, and explain how you know this to be true. (We will award some credit for recognizing there is an error.) For full credit, explain your reasoning carefully, show all steps neatly, and **box** your answers. Cross out any work you decide is incorrect, with an explanation in the margin.

You may answer the questions in any order you wish, but please clearly label each problem by number to ensure that it is properly graded.

DO NOT OPEN THIS EXAM UNTIL YOU ARE TOLD TO DO SO! GOOD LUCK!

PROBLEM 1 (10 points): Dimensional analysis. Even if you are unfamiliar with the following statements, determine whether they are correct or incorrect, based on a dimensional analysis of the equation stated for a given solution (i.e., check that the units on the left-hand side of the equation are the same as the units for the right-hand side of the equation). Show your reasoning.

(a) "The frequency f of a simple pendulum is given by

$$f = \frac{1}{2\pi}\sqrt{\frac{l}{g}} \tag{1}$$

where l is the length of the pendulum, and g is the acceleration due to Earth's gravity."

(b) "The range R of a cannon ball shot from a muzzle inclined at an angle θ_0 at a muzzle speed of v_0 is given by

$$R = 2\frac{v_0^2}{g}\cos\theta_0 \sin\theta_0 \tag{2}$$

where g is the acceleration due to Earth's gravity."

(c) "The acceleration a of an object undergoing uniform circular motion is given by

$$a = \omega v \tag{3}$$

where ω is the angular speed of the object, and v is its linear speed."

(d) "The magnitude of the force of gravitational attraction F between two masses m_1 and m_2 is given by

$$F = G\frac{m_1 m_2}{r^2} \tag{4}$$

where $G = 6.67 \times 10^{-11}$ N·m/kg."

PROBLEM 2 (10 points): A block sliding to rest on an incline. A square block with a mass of one kilogram is sliding to rest on top of a long inclined plane, which inclined at an angle $\theta = 15.0°$ with respect to the horizontal. The coefficient of kinetic friction of the block with respect to the top surface of the incline is $\mu_k = 0.300$. Its initial speed is 0.500 meters per second down the ramp.

(a) Does the block ever come to a complete halt on the incline?

(b) If so, how far does it slide on top of the incline before it comes to a complete halt?

PROBLEM 3 (20 points): An decelerating racecar on a circular racetrack. A racing car is decelerating as it drives around a very large circular racetrack, whose radius is $r = 1.00$ km. This deceleration is due to the sudden deployment at $t = 0$ of a parachute when the car is located at $\theta_0 = 0$ with respect to the x-axis. The car's velocity v_0 points along the y-axis at $t = 0$, and the z-axis is vertical. The car's initial speed at $t = 0$ is 300 kilometers per hour. The angular position of the car is found to be given by $\theta(t) = \omega t - \frac{1}{2}\alpha t^2$

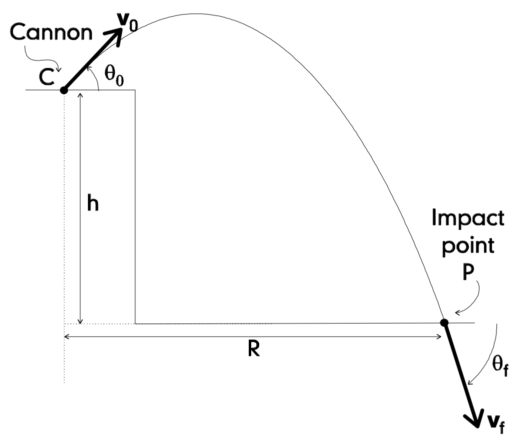

Figure 1: Figure for Problem 4

as measured by an observer located at the center of the racetrack, where α is measured to be 1.96×10^{-2} radians per second squared.

(Problem 3 continued) (a) What is ω? What are the x and y components of the instantaneous velocity $\mathsf{v}(t)$ of the car at all later times $t > 0$? What are the x and y components of the instantaneous acceleration $\mathsf{a}(t)$ of the car at all later times $t > 0$?

(b) How long does it take for the car to come to a complete halt?

(c) Assuming that the mass of the driver is 50.0 kg and that she is wearing a seat belt, what is the magnitude of the net weight $\mathsf{W}_{\mathsf{net}}$ that she experiences at $t = 0$, and in what direction does $\mathsf{W}_{\mathsf{net}}$ point with respect to the vertical? (HINT: What direction would a plumb bob attached inside the car point?)

PROBLEM 4 (20 points): A cannon ball shot over the edge of a cliff (see Figure 1). You may neglect air drag in solving this problem. A cannon ball is being shot at point C with an initial (muzzle) velocity v_0 at an angle of θ_0 with respect to the horizontal, over the edge of a cliff. The muzzle speed of the cannon ball is a fixed quantity v_0, but the angle θ_0 can be arbitrarily adjusted. The height of the cliff is h.

(a) How long does it take for the cannon ball to reach the impact point P?

(b) What is the range R of the cannon ball?

(c) What is the angle θ_f with respect to the horizontal with which the cannon ball strikes the final impact point P in Figure 1?

(d) What is the speed v_f of the cannon ball at the moment of impact at point P?

(e) Now suppose that the height h of the cliff is very high, so that $h >> v_0^2/2g$. What is the choice of the angle θ_0 in this limit of very large h that would permit the longest possible range R? What is the value $R_{\max}$ at this optimum choice of the angle θ_0 in this limit of very large h?

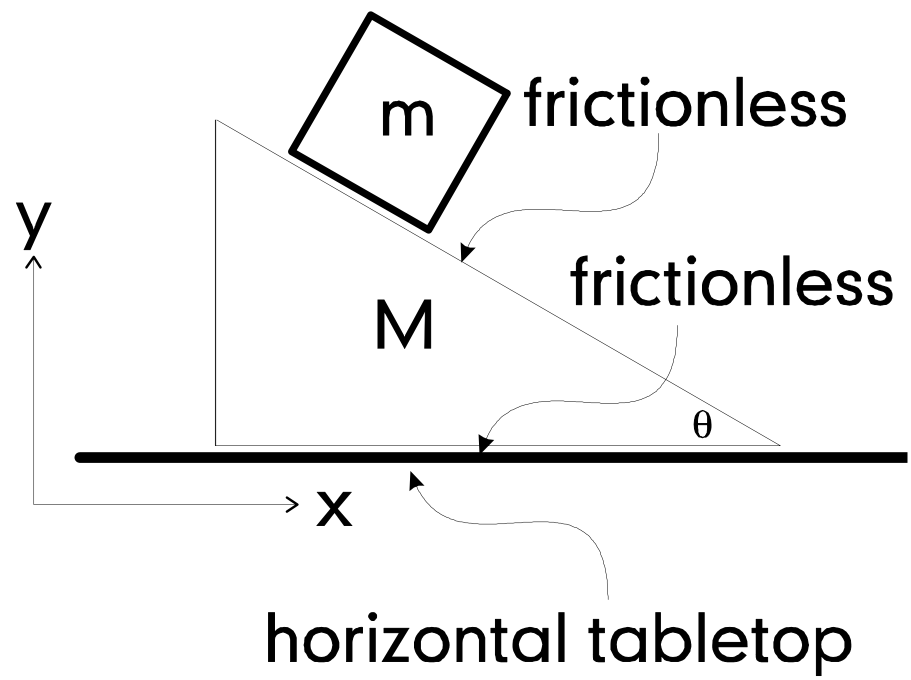

Figure 2: Figure for Problem 5

PROBLEM 5 (20 points): A wedge with a block on its top (see Figure 2). A wedge of mass M with an incline angle of θ with respect to the horizontal x-axis, has a smaller block of mass m, which can slide frictionlessly on its top surface, placed initially motionlessly onto this surface. Its bottom surface, which makes contact with a horizontal tabletop, is also frictionless. Draw a FBD for each body of this system of bodies. The blocks m and M are both released from rest at $t = 0$.

(a) What are the x and y components of the accelerations of the two masses m and M for $t > 0$?

(b) What are the x and y components of the normal force exerted on the smaller block m by the wedge M for $t > 0$?

(c) What are the x and y components of the normal force exerted by the tabletop onto wedge M for $t > 0$?

(d) Now let M become very large. What is the answer to part (a) in this case?

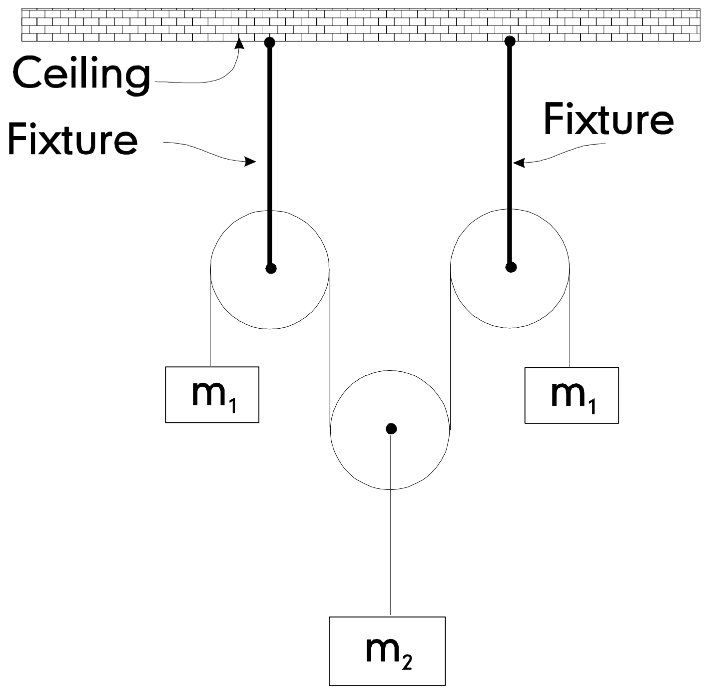

Figure 3: Figure for PROBLEM 6

PROBLEM 6 (20 points): System of masses, pulleys, and strings. Two blocks both having equal masses m_1 are hung from the left and right pulleys as shown in Figure 3, with a middle mass m_2 hanging freely from the middle pulley. The pulleys of this system are massless, and possess frictionless axles. The strings of this system are massless and possess fixed lengths. The left and right pulleys are attached by means of rigid fixtures from their centers to the ceiling. The (grooved) middle pulley, which is attached by a massless string from its center to the hanging mass m_2, is not attached to the ceiling, and hence is free to move.

(a) Draw a FBD for each mass in this system of masses. Also draw a diagram for the strings and pulleys of the system, and explain your reasoning concerning the constraints that the fixed string lengths place on the motion of the bodies in the system. Assume that $m_2 > 2m_1$. The system is released from rest at $t = 0$.

(b) What are the accelerations of the masses m_2 and $m_1$for $t > 0$?

(c) What is the tension in the left string connected to mass m_1 after the system has been released from rest for $t > 0$?

(d) What is the tension in the central string connected to mass m_2 after the system has been released from rest for $t > 0$?