University of California, Berkeley

Physics 7A.2 First Midterm Exam **Instructors: M. Reinsch / A. Lee** **Fall 2020**

Version **B**: 8:10 pm–10:15 pm (Pacific Time), Tuesday, September 29, 2020 Serial Number: 513C
to be administered online (via *bCourses* and *Gradescope*)
Upload exam by 10:25 pm

You may download the exam in advance, and start as soon as the password is made available. When time is called, please stop working, scan, photograph, or otherwise digitize your exam, and upload it as instructed to *Gradescope*. Make sure all pages you want graded are included, and ordered correctly.

PLEASE INCLUDE on the FIRST page of your submitted work the following:

UCB Physics 7A.2, Fall 2020, Midterm #1, Version B ***serial #*** ***date* (09/29/2020)**
your first and last name (clearly printed) ***your student ID #***
your discussion section # and/or meeting time ***your signature***

Your signature is required, and will signify that you understand and agree to all exam policies mentioned herein.

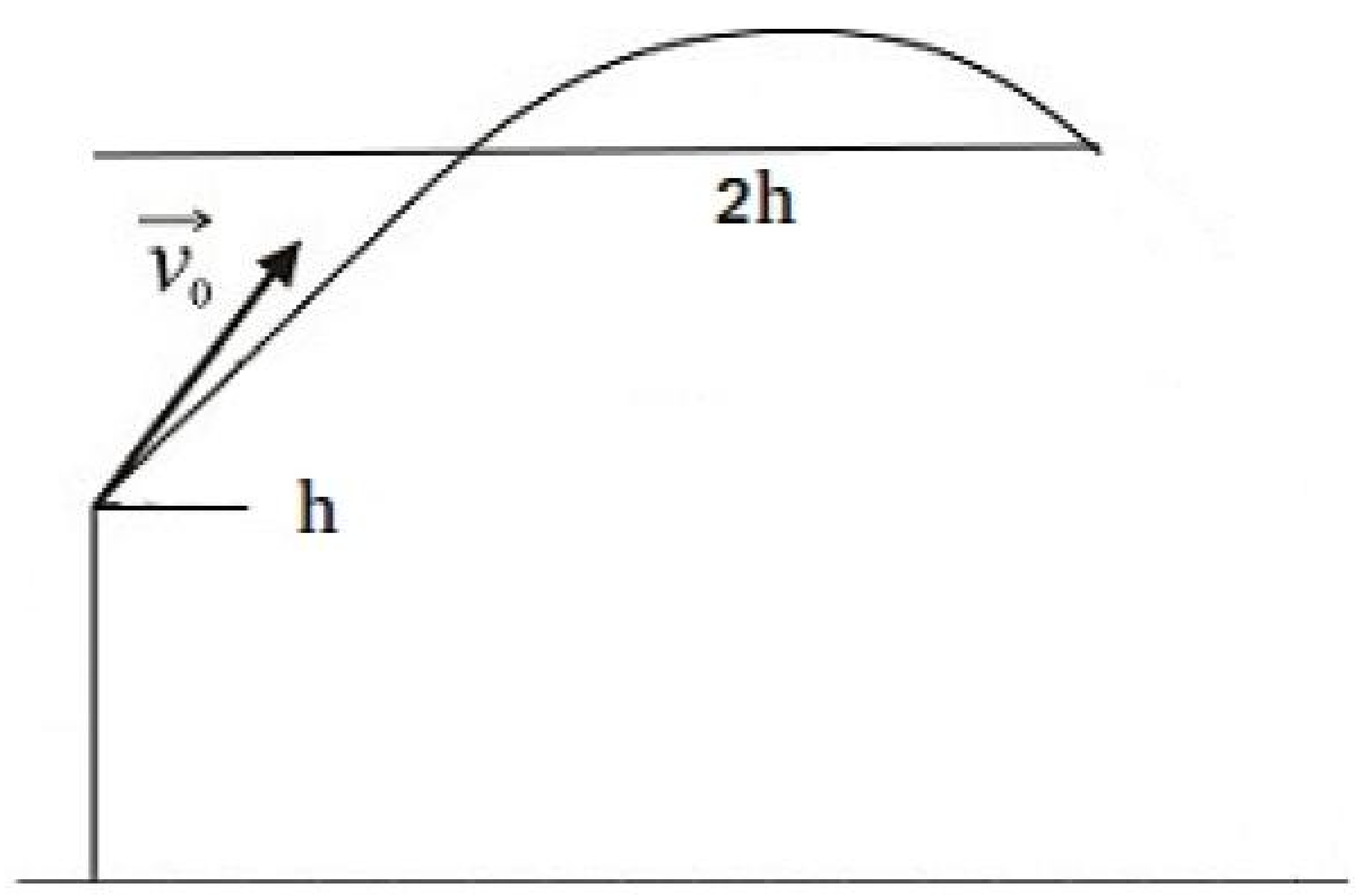
Problem	Suggested Time	Points
1	30 min.	25
2	30 min.	25
3	30 min.	25
4	30 min.	25
TOTAL	120 min. +15 min. for uploading	100

Each of the FOUR problems is divided into multiple parts each worth 5 points. Each part of each problem will be graded holistically, and your score on any problem will be the sum of your scores on all constituent parts. Your overall score will be the sum of your scores on all problems. You are allowed to use any of our course materials (e.g., your notes, the *bCourses* website, *Giancoli*, the *Physics 7A Workbook*, etc.). You may NOT consult any outside references or resources, or communicate in any way with any other persons or organizations except our online instructors for the duration of the exam. A calculator is allowed, but no other electronic computational aids, applications, or assistance may be used.

Begin by looking through the entire exam quickly. You may make use of any results from lectures, classes, discussion, labs, or in *Giancoli*, Chapters 1–5. Except where otherwise noted, your answers can rely on or refer to any previous responses. Remember to *briefly* but *clearly* justify all answers, and *briefly* explain major logical steps, even or especially if little or no actual calculations are involved. Work steadily to maximize partial credit; try to write something for every part of every problem. If you cannot finish a problem, explain briefly *how* you would proceed if you had more time. Draw diagrams. Remember to carefully specify any coordinate systems, variables, or parameters that you introduce, and clearly label any coordinate axes and free-body or other diagrams. Be careful with sign conventions and dimensions. Be sure to specify both the magnitude and direction of vectors unambiguously. You may complete the problems in whatever order you prefer. Pace yourself adequately, and do not spend too much time on any one problem. Good Luck!

1. Super-athlete Baseball [25 points]

In this problem we use an x axis that is horizontal and a y axis that points vertically upwards. At time $t = 0$, a baseball player hits a baseball at the location $x = 0$, $y = h$, where h is a positive constant. The components of the initial velocity vector are (v_{x0}, v_{y0}). Both v_{x0} and v_{y0} are positive values. The baseball player is a super-athlete and is able to run so fast that she can catch the baseball that she originally hit at $t = 0$. She does this by running along the x axis with constant acceleration a, starting from the origin with zero velocity. When she catches the baseball, its y coordinate is $2h$ and its velocity component in the y direction is negative. Neglect any aerodynamic forces on the baseball.



Player hitting a baseball before immediately running to catch the ball.

(a) [5 points] Write out equations for the x and y coordinates of the baseball as functions of time, valid after the ball is struck and before it is caught.

(b) [5 points] What minimal value for v_{y0} must we assume so that the baseball does in fact reach the y value $2h$?

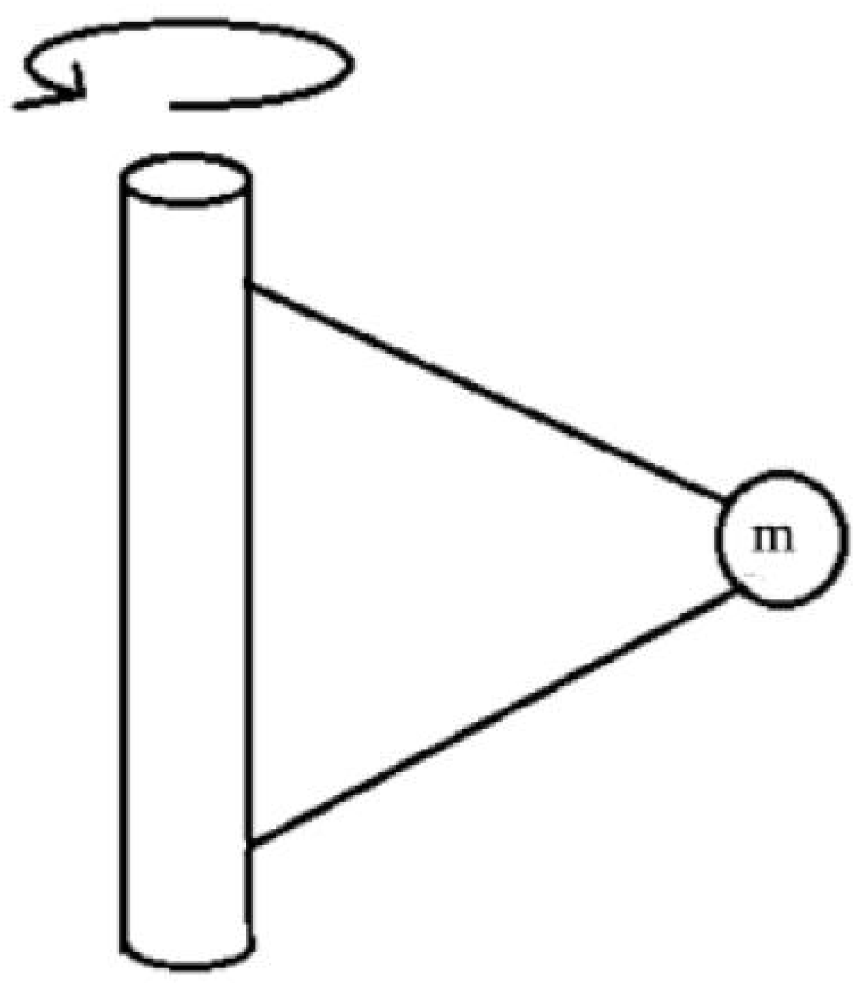
(c) [5 points] Assuming a value for v_{y0} that is greater than the value you computed in part (b), calculate the two time values, t_1 and t_2, for which the baseball's y coordinate equals $2h$. (We choose notation so that $t_2 > t_1$).

(d) [5 points] What is the y component of the baseball's velocity at t_2?

(e) [5 points] Calculate the acceleration of the baseball player.

2. Spinny Thing [25 points]

As an astronaut you are very busy, but you do find the time to build the apparatus shown in the picture below. This is in a zero-g environment (there are "effectively" no gravitational forces acting on massive objects). There is a cylinder that rotates about a fixed vertical axis as shown by the curved arrow. A very small sphere of mass m is attached to the cylinder using two pieces of massless, inextensible string, both of length L. The points where the strings attach to the cylinder are separated by a distance L, so we have an equilateral triangle. We assume the radii of the sphere and cylinder are negligibly small compared to L. The speed of the sphere is v and it is a constant, so **we have uniform circular motion**. If the sine or cosine of an angle appears in your answers, you must express it in terms of integers like 1, 2, and 3, and possibly square-roots thereof.



Spinning cylinder with a mass attached by two strings.

(a) [5 points] First let's check our math skills. Calculate $\sin 30°$ and $\cos 30°$ (sine and cosine of 30 degrees) as per the instructions above. If you are unsure how to proceed, draw an equilateral triangle and divide it into two pieces.

(b) [5 points] Draw a free-body diagram for the sphere and calculate the tension in the strings. Reminder: the tension in a string is a scalar.

For parts (c), (d), and (e) we have the familiar gravitational acceleration g at the surface of the Earth.

(c) [5 points] If you take this device back to Earth and show it to your friends, what will be the minimal value for v so that the lower string does not go slack (meaning the tension goes to zero)? Explain in detail; you should discuss the net force on m and the acceleration of m. Both of these are vectors.

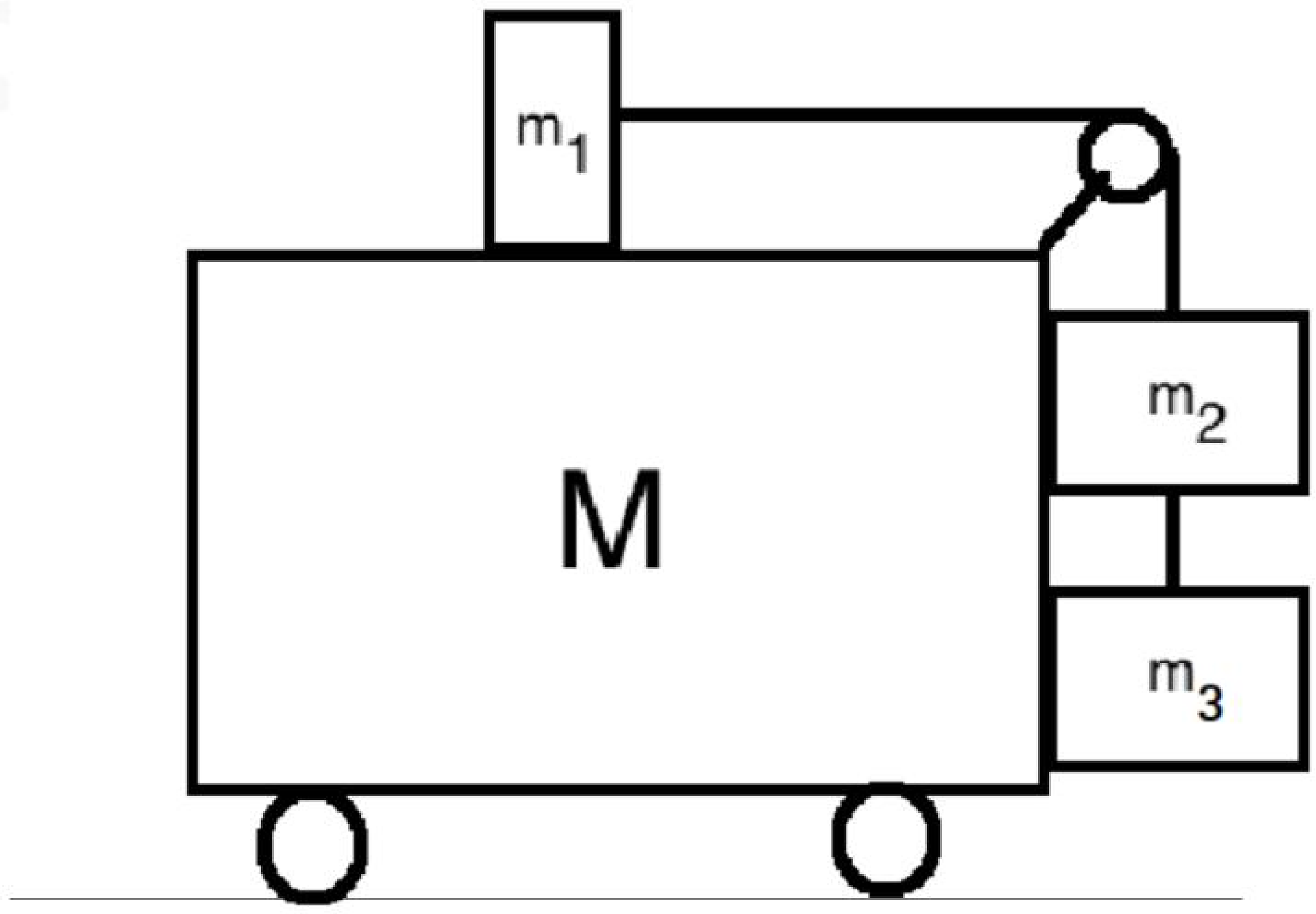
Now, adjust the apparatus so the axis of rotation is horizontal (that is, rotate the entire apparatus by 90° before spinning the cylinder).

(d) [5 points] Define v to be the minimum speed at the highest point such that neither string goes slack when the sphere is at its highest point. Calculate v.

(e) [5 points] If the value of v is now twice the value you computed in part (d), what is the tension in each string when the sphere is at the highest point?

3. Many Moving Masses [25 points]

In the Lecture Demonstration Room we have several carts for transporting laboratory equipment. The large rectangle represents such a cart (mass M; massless wheels). All surfaces are frictionless. There is one massless string (the "upper string") that goes from m_1 to m_2, passing over a massless pulley. There is a second massless string (the "lower string") connecting m_2 to m_3. Relative to the cart, m_2 and m_3 move purely vertically.



Moveable cart of mass M with a pulley system and three masses attached by massless, inextensible strings.

(a) [5 points] You hold m_1 and M so they do not move. Calculate the tension in the upper string. Calculate the tension in the lower string. Reminder: the tension in a string is a scalar.

(b) [5 points] Next we do a different experiment. You hold M so it does not move. (You are not touching m_1.) Draw Free Body Diagrams for the three small masses. Calculate the magnitude of the acceleration of m_1.

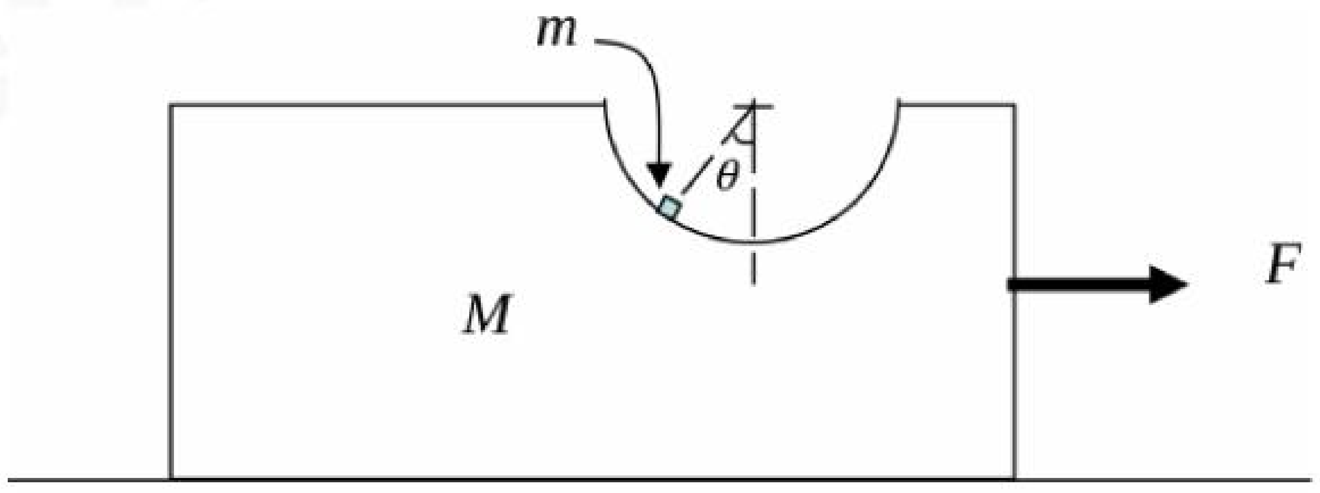
(c) [5 points] Next we do a different experiment. You apply a horizontal force to M (magnitude F) to the right. (You are not touching m_1.) The value of F is carefully chosen so that the small masses do not move relative to M. Calculate F.

(d) [5 points] Now suppose you double the magnitude of the applied force (twice the F found in (c)). Calculate the magnitude of the acceleration of M.

(e) [5 points] Continuing with part (d), calculate the tension in the upper string. Calculate the tension in the lower string.

4. Half-pipe Block [25 points]

Half of a cylinder is cut out of a large block with mass M sitting on a table. The side view is shown below. A small block of mass m and negligible size is placed as shown in the diagram. The coefficient of static friction between the small block and the large block is μ_s ($0 < \mu_s < 1$). You may assume that friction between the large block and the table is negligible. Any force applied to the large block is of magnitude F and to the right.



Large block with a smaller mass inside a cylindrical hole.

At first, the applied force F is zero. The small mass m is positioned at angle θ as shown above.

(a) [5 points] Draw a Free Body Diagram for m. This diagram should correspond to the scenario in part (b).

(b) [5 points] If the large block is motionless, what is the largest value of θ possible so that the small block remains motionless?

The applied force F (to the right) is now greater than zero.

(c) [5 points] Draw Free Body Diagrams for M and m. This diagram should correspond to the scenario in part (d).

(d) [5 points] Assuming θ is less than the value you computed above, what is the maximum value of F so that θ does not change (that is, the small block does not move relative to the large block)?

Now we glue the large block M to the motionless table (thus the values M and F are no longer needed). Suppose the mass m is sliding down the curved surface, with speed v and location given by θ at some instant. The coefficient of kinetic friction between the small block and large block is μ_k.

(e) [5 points] Draw a Free Body Diagram for m. Calculate the magnitude of the tangential acceleration of m. Calculate the magnitude of the radial acceleration of m. The given symbols are v, θ, μ_k and the radius R. (R is the radius of the cylindrical hole.) We are not solving a differential equation. We are just looking at one instant in time.