University of California, Berkeley

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

Version **C**: 8:10 pm–10:10 pm (PST) + 15 minutes for uploading
Tuesday, November 3, 2020 Serial Number: 52C
to be administered online (via *bCourses*, *Zoom*, and *Gradescope*)

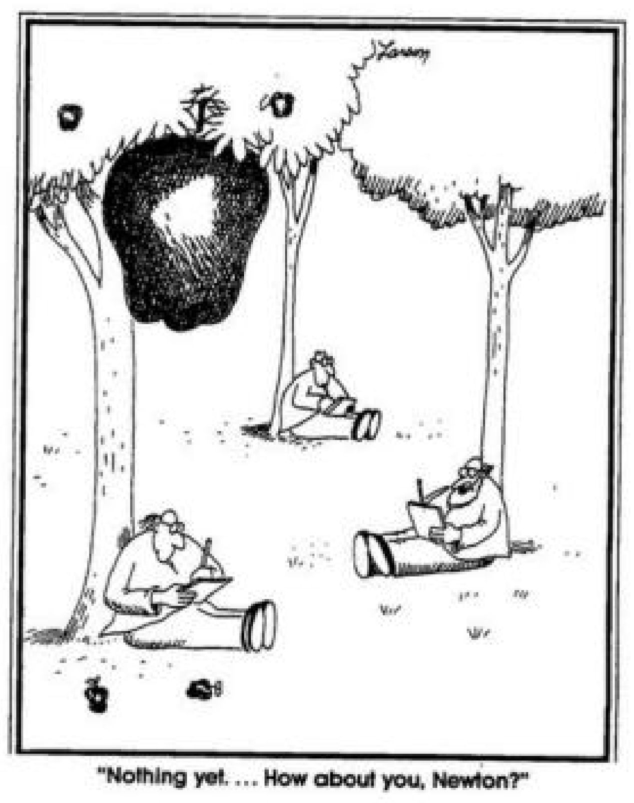
You may download the exam in advance, and start as soon as the password is made available. When time is called, please stop working, scan, photograph, or otherwise digitize your exam, and upload it as instructed to *Gradescope*. Make sure all pages you want graded are included, and ordered correctly.

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

UCB Physics 7A.2, Fall 2020, Midterm #2, Version C ***serial #*** ***date* (11/03/2020)**
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



"Nothing yet.... How about you, Newton?"

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. Raise your "hand" or initiate a chat on *Zoom* if you have a question. 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 1–9. 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. Look and listen for any corrections or clarifications from instructors on *Zoom*. Good Luck!

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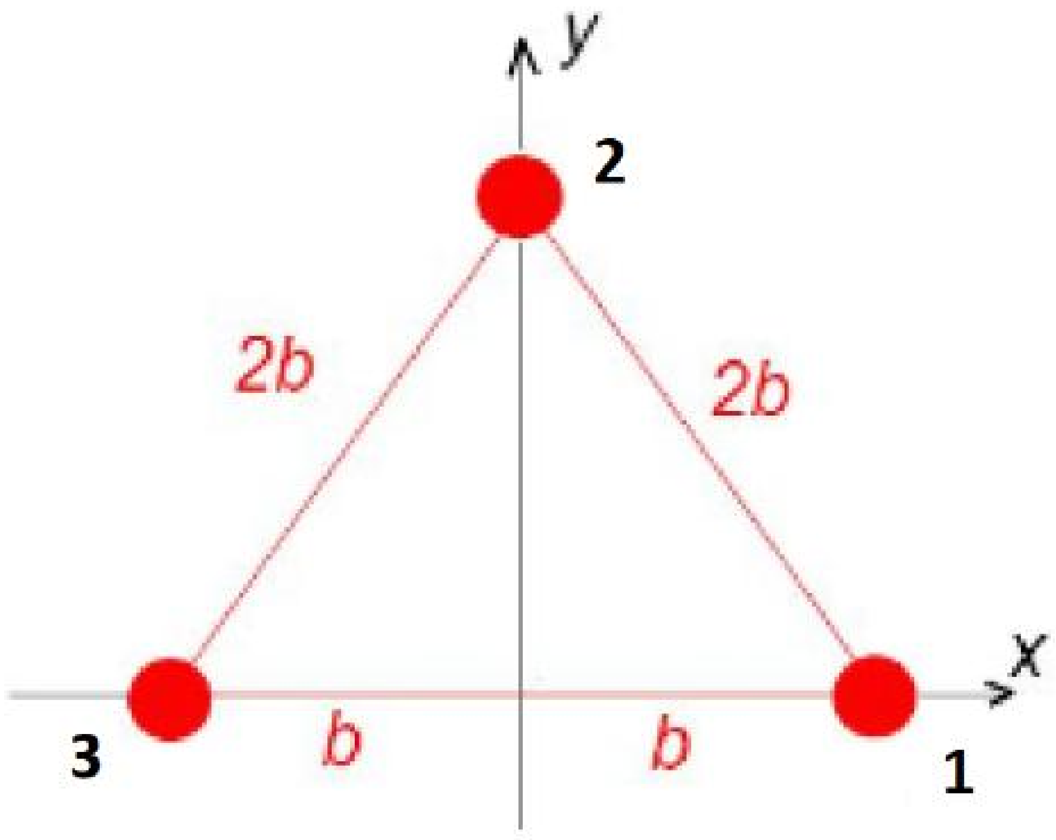
1. Ternary Star System [25 points]

Three stars are arranged as shown in the figure below. Note that they form an equilateral triangle with edge length $2b$. The mass of each star is M, and the stars may be treated as point masses. Note: the center of the triangle has a y coordinate of $\frac{b}{\sqrt{3}}$.



(a) [5 points] Calculate the y component of the total gravitational force on star 1 (located on the positive x-axis).

(b) [5 points] Calculate the x component of the total gravitational force on star 1 (located on the positive x-axis).

(c) [5 points] Calculate the gravitational field at an arbitrary location on the y-axis, between the origin $(0,0)$ and the center of the triangle. The location has an x coordinate equal to zero, and a y coordinate which we will simply call Y. (Reminder: The gravitational field is a vector.)

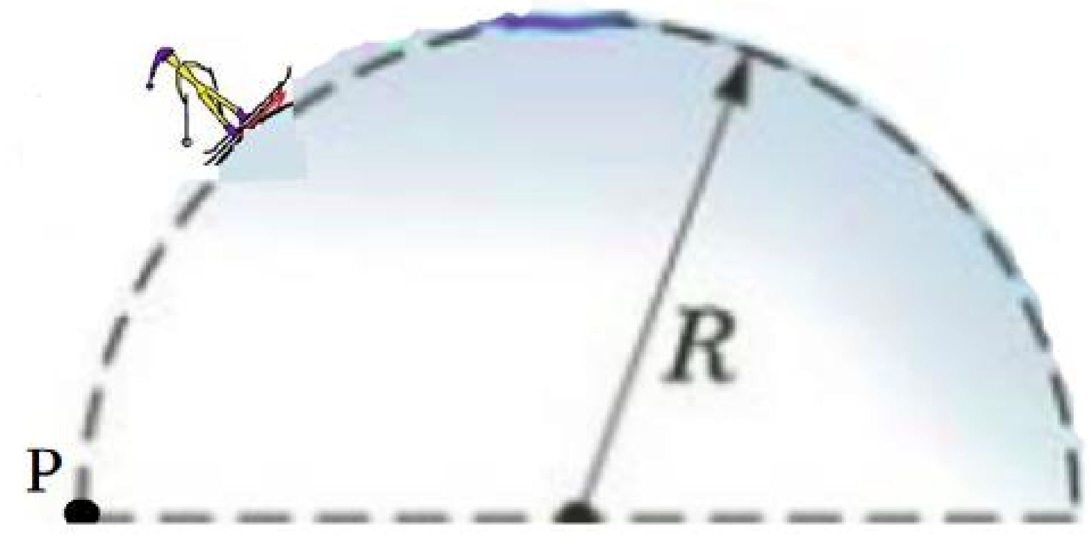
Define W to be the work done by the total gravitational field acting on a small test particle of mass m, as it moves along a straight line path from the center of the triangle to the origin.

(d) [5 points] Using your result from part (c), write an integral expression for W, but do not solve the integral. (We assume the stars are motionless).

(e) [5 points] Use your knowledge of Gravitational Potential Energy to determine the value of W.

2. Jet Pack Skiing [25 points]

A skier uses a jet pack to travel from the point P (in the lower left) to the top of a hemispherical hill of radius R. A jet pack is a backpack that exerts a (possibly time-dependent) force on the skier. Assume the snow is frictionless. The skier starts from rest at the point P and reaches the top of the hill with speed v_{top}. The skier can be treated as a point mass because the hill is much bigger than the skier. We define m = total mass (skier + jet pack). The change in mass of the jet pack can be ignored. Assume a frictionless safety mechanism keeps the skier from lifting off the hill.



Skier using a jet pack along a hill of radius R.

We use s to denote the distance traveled along the snowy surface, starting at P. Note that $s = \frac{\pi R}{2}$ at the top of the hill.

(a) [5 points] Calculate the work done by the jet pack on the skier.

(b) [5 points] Calculate the work done by the normal force on the skier.

(c) [5 points] Assuming the force due to the jet pack is parallel to the surface of the hill, and assuming that the speed is proportional to s ($v = qs$, where q is a constant), calculate the magnitude of the jet pack force as a function of s.

For this sub-problem, we will work with different assumptions. Assume the magnitude of $\vec{F}_{\text{jet}}$ (still parallel to the hill's surface) is a constant F_0 for the first half of the journey, and zero for the second half. Note: 'first half' means up to $s = \frac{\pi R}{4}$.

(d) [5 points] Calculate the value of F_0 needed for the skier to reach the top with speed v_{top}.

In the previous parts, v_{top} was a given value; now it is a variable you may need to find. For this sub-problem, assume $\vec{F}_{\text{jet}}$ has a constant magnitude and direction, pointing in the $(\hat{\mathbf{i}}+\hat{\mathbf{j}})/\sqrt{2}$ direction (towards the upper right) for the entire journey.

(e) [5 points] What is the minimum magnitude of this constant force so that the skier can begin the journey? What is the resulting minimal value for v_{top} when the skier gets to the top?

3. Sliding Masses [25 points]

Two particles move on a horizontal frictionless surface. Particle 1 has a mass m_1 and initial speed v_1, moving in the $+x$ direction. Particle 2 has a mass m_2 and initial speed v_2, moving in the $(\hat{\imath} + \hat{\jmath})/\sqrt{2}$ direction.

(a) [5 points] If the particles collide and stick together, what are the x and y components of the velocity vector after the collision?

(b) [5 points] Calculate the final total kinetic energy minus the initial total kinetic energy.

(c) [5 points] Calculate the change in the momentum vector of Particle 1 (that is, final minus initial). Your answer should state the x and y components of this vector.

(d) [5 points] For this sub-problem, we assume $m_1 = m_2$. What are the initial velocity vectors of each particle *relative to the center of mass*?

This is a completely separate problem. We study a collision in 1D. A soccer ball (mass $= m_s$) has initial velocity v_0. A very massive bowling ball (mass $= m_b$) is initially at rest. After the collision, the total kinetic energy of the system is 5/6 of its original value.

(e) [5 points] Calculate v_b, the velocity of the bowling ball after the collision.

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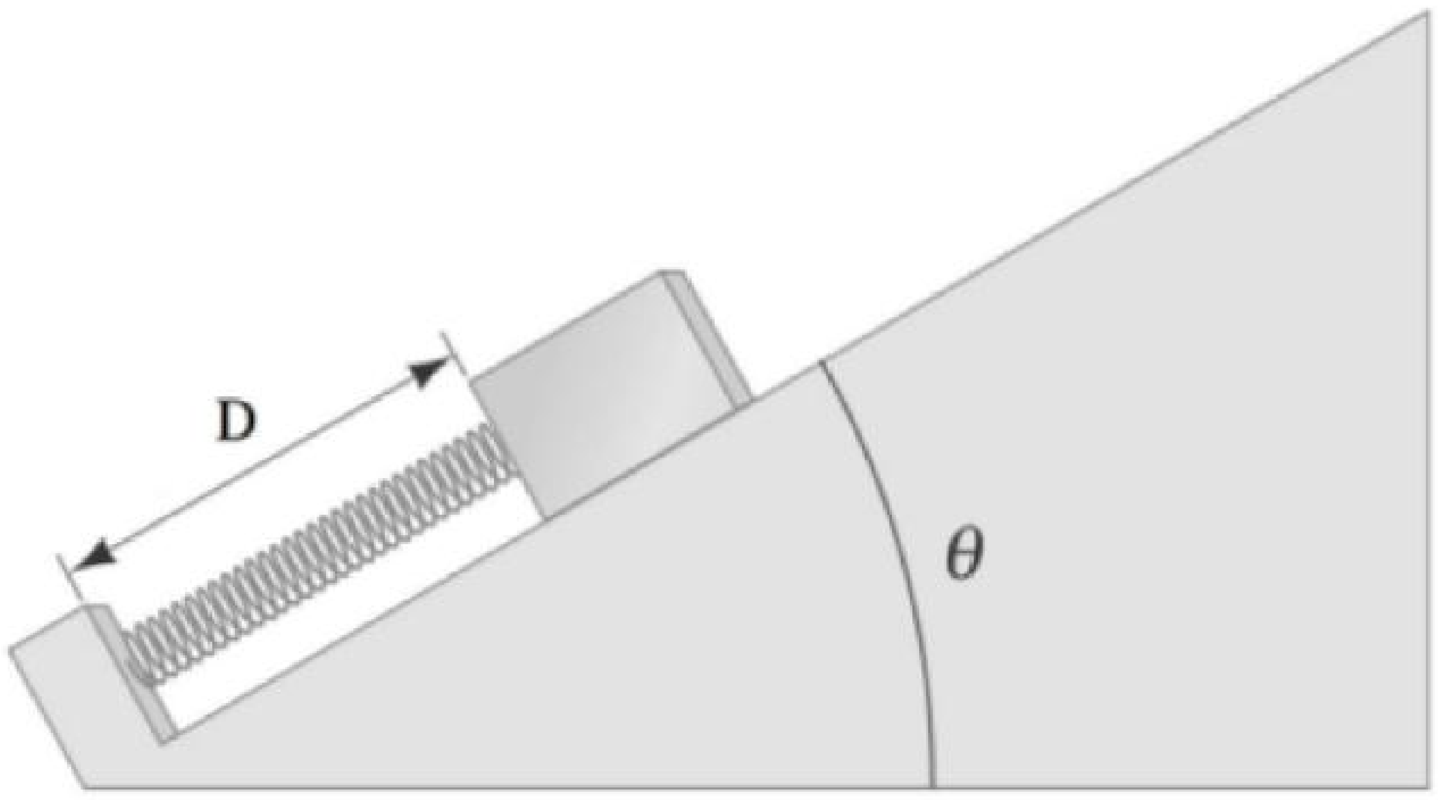
4. Sloped Spring [25 points]

A massless spring has an unstretched length of D_0 (this is the length of the spring when it is removed from the apparatus). A mass m is attached to its free end and the spring is compressed to a length D along a frictionless slope. The spring is then released. Note that "attached" means the spring can pull back on the mass.



Compressed spring and mass on a frictionless slope before releasing the spring.

(a) [5 points] Calculate the value for the spring constant k so that the mass remains motionless after being released. Express your answer in terms of D, D_0, m, g, and θ.

(b) [5 points] Assuming k is greater than the value you found in part (a), the mass will initially move up the slope. Some time later the mass will again be (instantaneously) at rest. We would like this to occur when the length of the spring is D_0. Calculate the value for the spring constant k so this is the case. Express your answer in terms of D, D_0, m, g, and θ.

(c) [5 points] Continuing part (b), what is the maximal speed, and what is the length of the spring when this is achieved?

(d) [5 points] Calculate the work done by the spring on the mass, from the time the mass is initially released until the point where the speed is maximal.

This is a completely separate problem: Draw a circle of radius R in the xy-plane, centered at the origin. Consider the half of the circle that has $x \geq 0$. That is where we place a piece of uniform wire bent into half of a circle.

(e) [5 points] Calculate the location of the center of mass for this wire.

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