SMU Department of Physics
QUALIFYING EXAMINATION
Saturday , August 20, 2016
9:00AM to 12:00PM

Classical Mechanics

Three hours are permitted for the completion of this section of the examination. There are 5 problems included in this section, each is worth 20 points. Apportion your time carefully.

Please write only on ONE SIDE of the paper, and DO NOT staple your sheets; they will be scanned in the auto-feeder. Clearly mark your initials on each page, and number each of your pages.

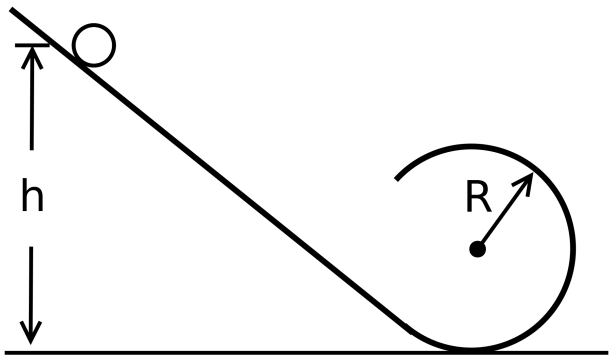
No reference materials or books are permitted. (If you believe there is a key piece of information or formula missing you may ask the proctor to check; but we've checked this carefully.)

Simple calculators are permitted; cell phone calculators can NOT be used.

Questions should be directed to the proctor.

Good Luck!

1. As shown in the figure, a solid brass ball of mass 0.271 g will roll smoothly along a loop-the-loop track when released from rest along a straight section. The circular loop has radius $R = 0.05$ m, and the ball has radius $r \ll R$. What is h if the ball is on the verge of leaving the track when it reaches the top of the loop?



2

A spider is hanging by a silk thread from a tree in Dallas. Find the orientation and the value of the equilibrium angle that the thread makes with the vertical (i.e. with the direction of gravity), taking into account the rotation of the Earth. Assume that the latitude of Dallas is $\theta \approx 33$ and the radius of the Earth is $R \approx 6,400$km. *[Important; note the spider is stationary. This should simplify the problem. Think.]*

3) Note $s = |p_1 + p_2|^2$ for 4-vectors p_1 and p_2.
(I need to see work; no credit if you happen to have memorized any of these answers.)

a) Compute the invariant energy $\sqrt{s}$ for a fixed target system for a proton beam of mass m and a proton target of mass m. Express the result in terms of the beam energy E and the proton mass. (Eliminate the proton 3-momentum.) [Please DO NOT neglect m^2 terms.]

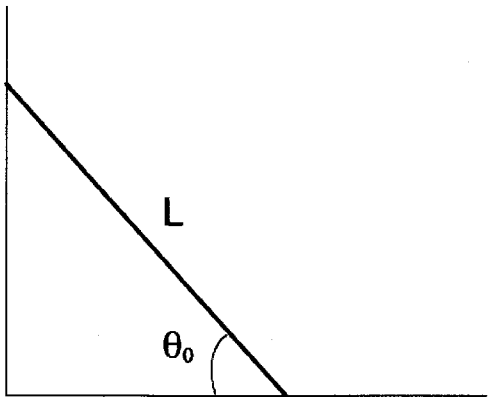
b) Compute the invariant energy $\sqrt{s}$ for a collider system for two proton beams of mass m and energy E. Express the result in terms of the beam energy E and the proton mass. [Please DO NOT neglect m^2 terms.]

c) For a fixed target system compute the minimum beam energy E that you need to create anti-protons via the reaction $pp \to ppp\bar{p}$. Express the result in terms of the proton mass.

d) For a collider system compute the minimum beam energy E (<u>each</u> beam has energy E) that you need to create anti-protons via the reaction $pp \to ppp\bar{p}$. Express the result in terms of the proton mass.

4

3. A uniform ladder of mass M and length L is placed with one end against a frictionless wall and the other end on a frictionless floor. The ladder initially makes an angle θ_0 with the floor, as shown below.



The ladder is released, and slides under the influence of gravity.

(a) Write the Lagrangian for the sliding ladder as a function of θ (the angle of the ladder with respect to the floor).

(b) At what angle θ does the ladder lose contact with the wall?

(Note: The moment of inertia of a uniform rod of mass M and length L rotating about an axis through its center of mass is $I = \frac{1}{12}ML^2$)

5. A pendulum of length L and mass m is connected to a block also of mass m that is free to move horizontally on a frictionless surface. The block is connected to a wall with a spring of spring constant k. For the special case where

$$\sqrt{\frac{k}{m}} = \sqrt{\frac{g}{L}} = \omega_0 \tag{1}$$

determine:

(a) The frequencies of the normal modes of this system for small oscillations around the equilibrium positions.

(b) The motion of each of the normal modes.