Massachusetts Institute of Technology
Experimental Study Group

Physics 8.012 **Fall 2010**

Exam 2

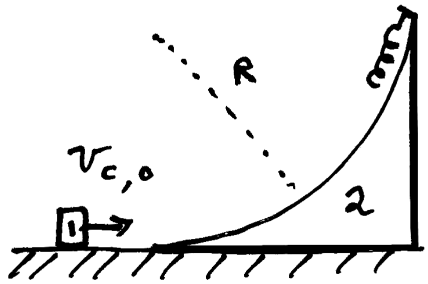
Name ____

The following exam consists of three problems. Answers without work shown will not be given any credit. Good luck!

Problem 1	**(30 Points)**	____________________
Problem 2	**(35 Points)**	____________________
Problem 3	**(35 Points)**	____________________
Total	**(100 Points)**	____________________

Problem 1 (30 points)

A block of mass m_b sits at rest on a frictionless table; the block has a circular surface of radius R as shown in the figure. A small cube of mass m_c and speed $v_{c,0}$ is incident upon the block; the cube slides without friction on the table and slides without friction up the block. At the top of the block, the cube compresses a spring of spring constant k until it momentarily comes to rest a height R above the table. The cube then slides back down until it leaves the block.



(a) How much did the spring compress?

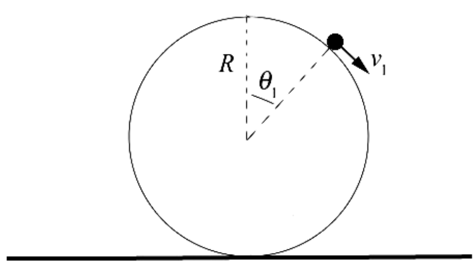
(b) What is the final speed of the block when the cube is no longer on it?

Problem 2 (35 points)

A particle initially sits on top of a large smooth sphere of radius R as shown in the figure. The particle begins to slide along the surface of the sphere. There is a friction force between the particle and the surface that varies with the angle θ according to

$$f = f_0 \sin\theta$$

where f_0 is a constant. Let g denote the gravitational constant.



(a) Determine the angle θ_1 with respect to the vertical at which the particle will lose contact with the surface of the sphere.

(b) What is the speed v_1 of the particle at the instant it loses contact with the surface of the sphere.

Problem 3 (35 points)

A rocket sled ejects gas backwards at a speed u relative to the rocket sled. The mass of the fuel in the rocket sled is equal to one half the initial total mass $m_{r,0}$ (including fuel) of the sled. The rocket sled starts from rest on a frictionless track. You may ignore air resistance.

(a) Derive a relation between the differential of the speed of the rocket sled, dv, and the differential of the total mass of the rocket, dm_r.

(b) Integrate the above relation to find the speed of the rocket sled as a function of mass, $v_r(m)$, as the rocket sled speeds up.

(c) What is the final speed of the rocket sled after all the fuel has been burned? Express your answers in terms of the quantities u, and $m_{r,0}$ as needed.

(d) After reaching its final speed, the sled enters a rough portion of the track that begins at $x = 0$ with a coefficient of kinetic friction that varies with distance $\mu_k(x) = bx$ where b is a positive constant. How far D did the sled slide before it came to rest in that portion of the track? Express your answers in terms of the quantities u, b, and m_0 as needed.