The Boston Area Undergraduate Physics Competition

April 17, 1999

Name: _____

School: _____

Year: _____

Address: _____

_____

e-mail: _____

Phone: _____

Do not turn this page until you are told to do so.

You have four (4) hours to complete this exam.

Please provide the information requested on this cover sheet. At the end of the exam, hand in this cover sheet with your solutions. You may keep the exam questions.

Show all relevant work in your exam books. Please write neatly. Partial credit will be given for significant progress made toward a correct solution.

You must be enrolled in a full-time undergraduate program to be eligible for prizes.

1999
Boston Area Undergraduate
Physics Competition

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Time: 4 hours

Each of the six questions is worth 10 points.

1. (a) Consider a solid sphere of uniform charge density. What is the ratio of the electrostatic potential at the surface to that at the center?

   (b) Consider a solid cube of uniform charge density. What is the ratio of the electrostatic potential at a corner to that at the center?

   (Take the potential to be zero at infinity, as usual.)

2. A wheel with spokes rolls on the ground. A stationary camera takes a picture of the wheel. Due to the nonzero exposure time of the camera, the spokes will generally appear blurred. At what location (locations) in the picture does (do) a spoke (the spokes) *not* appear blurred?

3. A motorcyclist wishes to travel in a circle of radius R. The coefficient of static friction between the tires and the (horizontal) ground is constant. The motorcycle starts at rest. What is the minimum distance the motorcycle must travel in order to achieve its maximum allowable speed (that is, the speed above which it must skid out of the circular path)?

4. (a) A fox chases a rabbit. Both run at the same speed v. At all times, the fox runs directly toward the instantaneous position of the rabbit, and the rabbit runs at an angle α relative to the direction directly away from the fox. Their initial separation is ℓ.

   When and where does the fox catch the rabbit (if it does)? If it never does, what is their eventual separation?

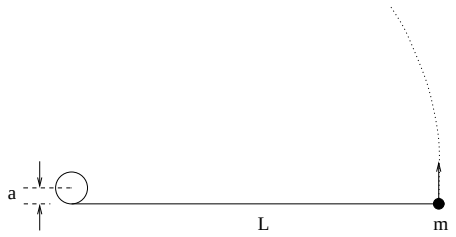
   (b) Consider the same situation, except now let the rabbit always move in the straight line of its initial direction in part (a).

   When and where does the fox catch the rabbit (if it does)? If it never does, what is their eventual separation?

5. Assume that a cloud consists of tiny water droplets suspended in air (uniformly distributed, and at rest), and consider a raindrop falling through them. After a long time, the raindrop moves with constant acceleration. Find this acceleration.

   (Assume that when the raindrop hits a water droplet, the droplet's water gets added to the raindrop. Also, assume that the raindrop is spherical at all times. Ignore air resistance on the raindrop.)

6. A mass m is attached to one end of a spring of zero equilibrium length, the other end of which is fixed. The spring constant is K. Initial conditions are set up so that the mass moves around in a circle of radius L on a frictionless horizontal table. (By "zero equilibrium length", we mean that the equilibrium length is negligible compared to L.)



At a given time, a vertical pole (of radius a, with $a \ll L$) is fixed onto the table next to the center of the circle, as shown. The spring winds around, and the mass eventually hits the pole. Assume that the pole is sticky, so that any part of the spring touching the pole does not slip. How long does it take for the mass to hit the pole?
(Work in the approximation where $a \ll L$.)