AAPT | UNITED STATES PHYSICS TEAM

AIP | 2000

Preliminary Exam
Open Response Questions

4 Questions, 60 minutes

INSTRUCTIONS
DO NOT OPEN THIS TEST UNTIL YOU ARE TOLD TO BEGIN

- Show all your work. Partial credit will be given.
- Start each question on a new sheet of paper. Be sure to put your name in the upper right-hand corner of each page, along with the question number and the page number/total pages for this problem. For example,

  Doe, Jamie
  Q1 – 1/3
- A hand-held calculator may be used. Its memory must be cleared of data and programs. You may use only the basic functions found on a simple scientific calculator. Calculators may not be shared. You may not use any tables, books, or collections of formulas.
- Each of the four questions is worth 25 points. The questions are not necessarily of the same difficulty.

Possibly Useful Information

Gravitational field at the Earth's surface	g	$= 9.8$ N/kg
Newton's gravitational constant	G	$= 6.67 \times 10^{-11}$ N·m^2/kg^2
Binomial expansion	$(1 + x)^n \approx 1 + nx$	for $\lvert x \rvert << 1$

Moment of Inertia about Center of Mass – Uniform Object
(will not be provided on the second screening exam)

Disk	$^1/_2\, MR^2$
Sphere	$^2/_5\, MR^2$
Rod	$^1/_{12}\, ML^2$

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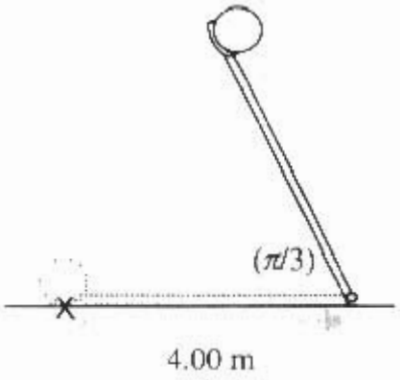
1. A 4.00-meter long catapult, hinged at ground level, is used to fire large rocks as shown in the diagram at the right. A rock starts from rest with the catapult arm horizontal and is accelerated uniformly until it is released when the catapult arm makes an angle of $(\pi/3)$ rad (= 60°) with respect to the horizontal and the rock has a tangential velocity of 10.0 m/s.

(17) a. How far from the original starting position (marked with an X in the diagram) does the rock land? The ground is level. Assume air resistance is negligible.

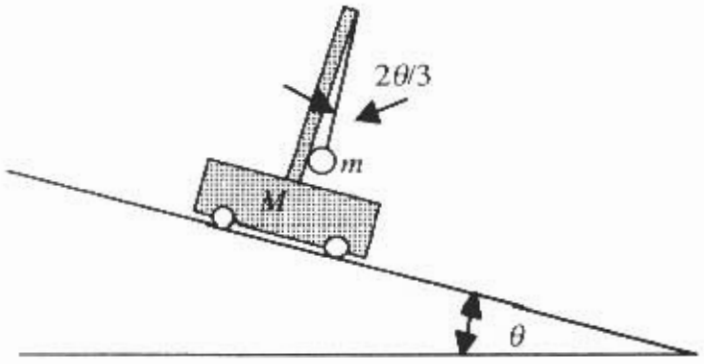
(8) b. What was the angular acceleration of the rock before its release?



2. An accelerometer consists of a ball of mass m attached to one end of a string. The other end of the string is attached to a cart of mass M. When the cart rolls down an inclined plane of angle θ with respect to the horizontal, the string makes a constant angle of $2\theta/3$ with respect to the vertical. See diagram at the right. Express your answers to the following in terms of known and given quantities. Assume air resistance is negligible.

(13) a. What is the acceleration of the cart?

(12) b. What is the coefficient of friction between the cart and the plane?



3. A uniform thin rod of length L and mass M is free to swing in a vertical plane about a frictionless horizontal axis through its upper end. Express your answers to Parts (a) and (b) in terms of M, L, and g. Assume air resistance is negligible.

(10) a. The rod is released from rest in a horizontal position. Find its angular velocity at the moment it reaches a vertical orientation.

(8) b. Suppose at this moment its bottom end collides totally inelastically with a stationary point mass M (the same mass as that of the rod). The point mass sticks to the rod. What is the angular velocity just after the collision?

(7) c. Numerically evaluate the maximum angle (with respect to the vertical) the rod attains after the collision.

4. A pendulum consists of a small metal sphere of mass M attached to 0.60-m massless string. It hangs from a support that is located 0.30 m to the right of and 0.40 m above a fixed small rod oriented perpendicular to the plane of swing. Assume that there is no friction between the rod and the string and ignore air resistance. The pendulum is pulled to the right and released from rest when the bob is located 0.15 m higher than the rod (See Fig. 1). As the pendulum swings to the left, the string contacts the rod and the sphere begins to loop around it (See Fig. 2). Ignore the diameter of the rod and take y to be the height of the sphere above the rod. Express your answers to the following in terms of y, M, and g.

Fig. 1

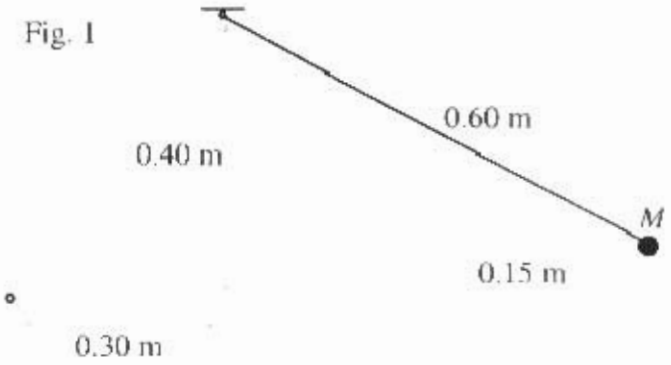
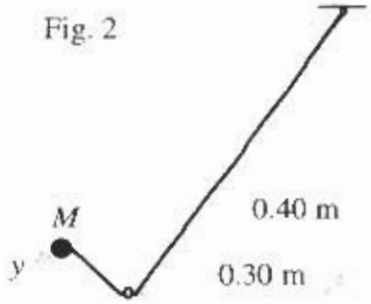


Fig. 2



(15) a. Find an expression for the tension T in the string when the string is in contact with the rod.

(10) b. Find the x- and y-components of the force that the rod exerts on the string.