AAPT | UNITED STATES PHYSICS TEAM
AIP | 2001

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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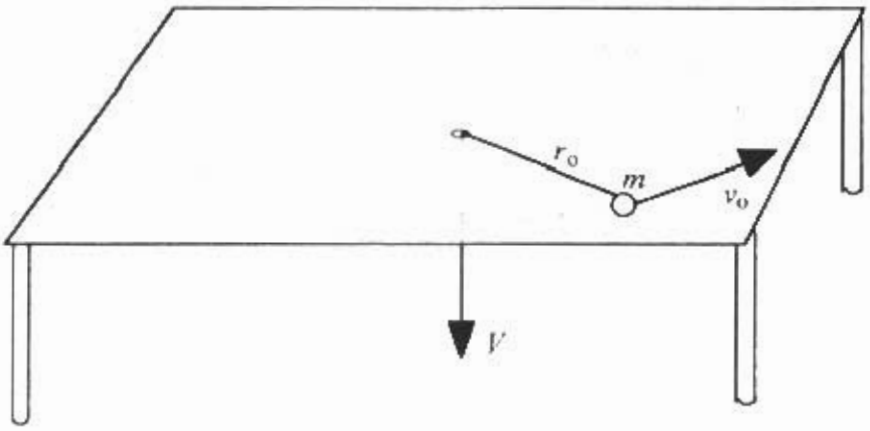


1. A mass m attached to a massless string moves around a circle of radius r_0 with speed v_0 on a frictionless table as shown in the accompanying diagram. The string passes through a small hole in the table. Starting at time $t = 0$, the string is pulled downward with a constant speed V. Determine:

(7) a. The tangential speed v of mass m as a function of r.

(6) b. The tangential speed v of mass m as a function of time t.

(6) c. The force needed to pull the string as a function of time t.

(6) d. The work done on the mass by the string from time $t = 0$ to time t.

2. Two twin asteroids of identical mass M are located a distance r apart. A probe of mass m (with $m << M$) is released from rest a distance A (with $A << r$) from the center of mass of the two-body asteroid system. The probe is an equal distance from both asteroids. Assume that the probe does not affect the separation distance r and that all other objects in the universe are too far away to exert a significant gravitational force. The asteroids must be orbiting their common center of mass in order to maintain a constant distance, but ignore any effects of orbiting in this problem. For both parts, clearly justify any approximations that you are making and give your answers in terms of r, A, G, M, and m.

(17) a. How long will it take for the probe to reach the center of mass?

(8) b. What will be the speed of the probe as it passes through the center of mass of the asteroid system?

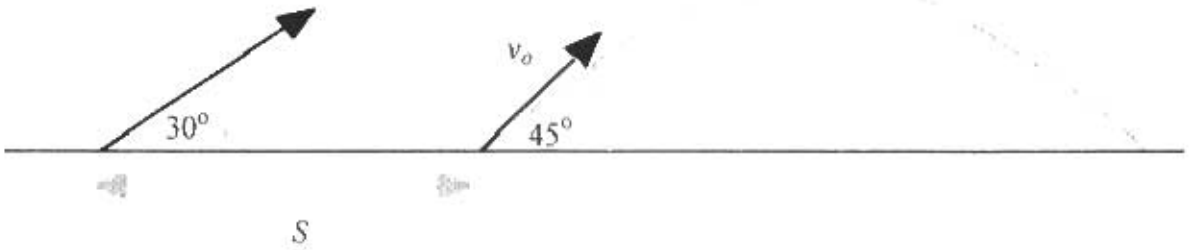
3. In this problem, please use $g = 10$ N/kg. A bead of mass 0.050 kg is placed on a long vertical wire which is firmly attached to both the floor and ceiling. As the bead slides on the wire the magnitude of the frictional force between the bead and the wire is a constant 0.20 N. The bead is released from rest at an initial height of 1.47 m above the floor. Assume all collisions with the floor are perfectly elastic and that air resistance can be neglected.

(9) a. What is the bead's greatest height after colliding with the floor?

(6) b. How much time does it take the bead to slide from its initial height of 1.47 m to the floor?

(5) c. How much time does it take the bead to travel from the floor to the height found in a) above?

(5) d. What is the total distance the bead travels before coming to rest?



4. A projectile is launched in a vertical plane from a fixed site. It has an initial velocity v_o at an angle of 45° above the horizontal. A second projectile is simultaneously launched at an angle of 30° from a second site a distance S directly behind the first one. See diagram above. They collide when the first projectile attains its maximum height. Ignore any effects of air resistance. Express your answers in terms of in terms of v_o and g.

(15) a. Find the separation S between the two launch sites. Hint: You will first need to find the initial velocity of the second projectile.

(5) b. What are the velocities of the two projectiles immediately before they collide? (You may leave your answers to this part and the following part in component form.)

(5) c. Assuming that the two projectile are identical small spheres of equal mass that collide elastically, what are the velocities of the two spheres immediately after they collide?