AAPT | UNITED STATES PHYSICS TEAM
AIP | 2005

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. Cell phones may not be used during the exam or while the exam papers are present. 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.
- Good luck!

Possibly Useful Information

Gravitational field at the Earth's surface	$g = 9.8\ \mathrm{N/kg}$
Newton's gravitational constant	$G = 6.67 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$
Average Earth-Sun Distance	$1\ \text{Astronomical Unit (A.U.)} = 1.5 \times 10^{11}\ \mathrm{m}$
Binomial expansion	$(1 + x)^n \approx 1 + nx \quad \text{for } \lvert x \rvert \ll 1$

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

Disk	$\frac{1}{2} MR^2$
Sphere	$\frac{2}{5} MR^2$
Rod	$\frac{1}{12} ML^2$

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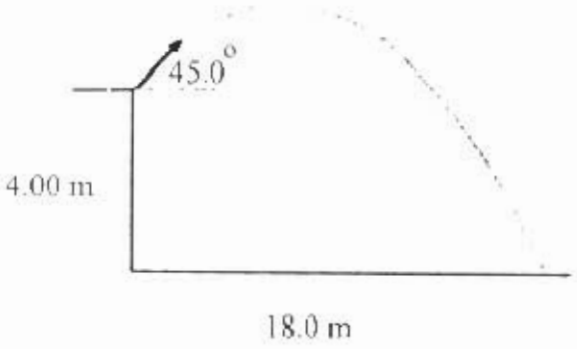
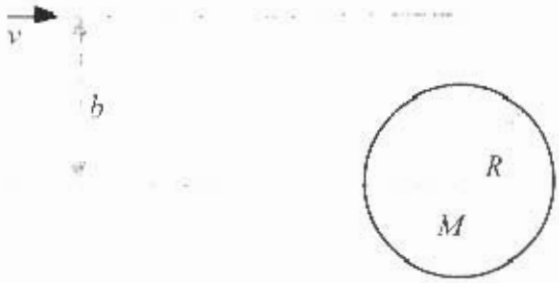
1. A shell is shot from the edge of a 4.00 m high cliff with initial velocity v_i at an angle of 45.0° above the horizontal. It lands 18.0 m from the base of the cliff as shown in the accompanying diagram.

(13) a. What is the initial speed v_i of the shell?

(12) b. A second shell is launched with the same initial velocity. At the top of its trajectory it explodes into two fragments. One fragment of mass m_1 has zero speed immediately after the explosion and falls vertically. The other fragment of mass m_2 lands 30.0 m from the base of the cliff. Find the ratio m_1/m_2.

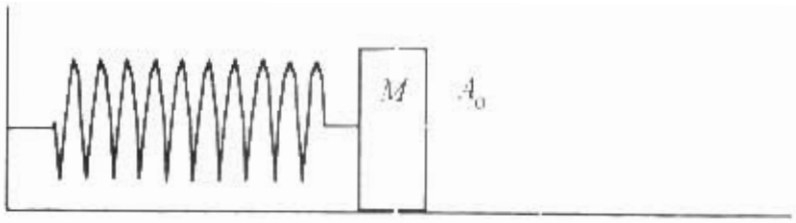


2. "Hit the planet, win a prize." A space probe is sent toward a distant planet which has mass M and radius R. When the probe is very, very far from the planet, the probe has speed v and is headed in a direction such that, if undeflected, it would pass a distance $b > R$ from the planet's center. See the accompanying diagram.



(10) a. Assuming that the probe hits the planet, what is the probe's speed just before it hits?

(15) b. What is the maximum initial speed the probe can have and still hit the planet?



Equilibrium
position

3. A mass M with weight Mg = 10.00 N is placed at the end of a massless spring with spring constant 100.0 N/m as shown in the above diagram. The coefficients of static and kinetic friction between the mass and the rough horizontal surface are 0.400 and 0.200, respectively. The spring is compressed a distance A_0 = 0.180 m from its equilibrium position and released from rest. Find the total distance the mass travels and where it comes to rest with respect to the equilibrium position.

Top View Side View

4. A thin disk of mass M, radius R, and height H is initially at rest on a flat horizontal table as shown in top and side views above. There is no friction between the disk and the table. A long massless cord is wrapped around the disk and pulled with constant force F parallel to the table.
(15) a. Find the ratio of rotational to translational kinetic energy.
(10) b. What is the total work done by the force F during the disk's first revolution?