AAPT | UNITED STATES PHYSICS TEAM
AIP | 2004

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!

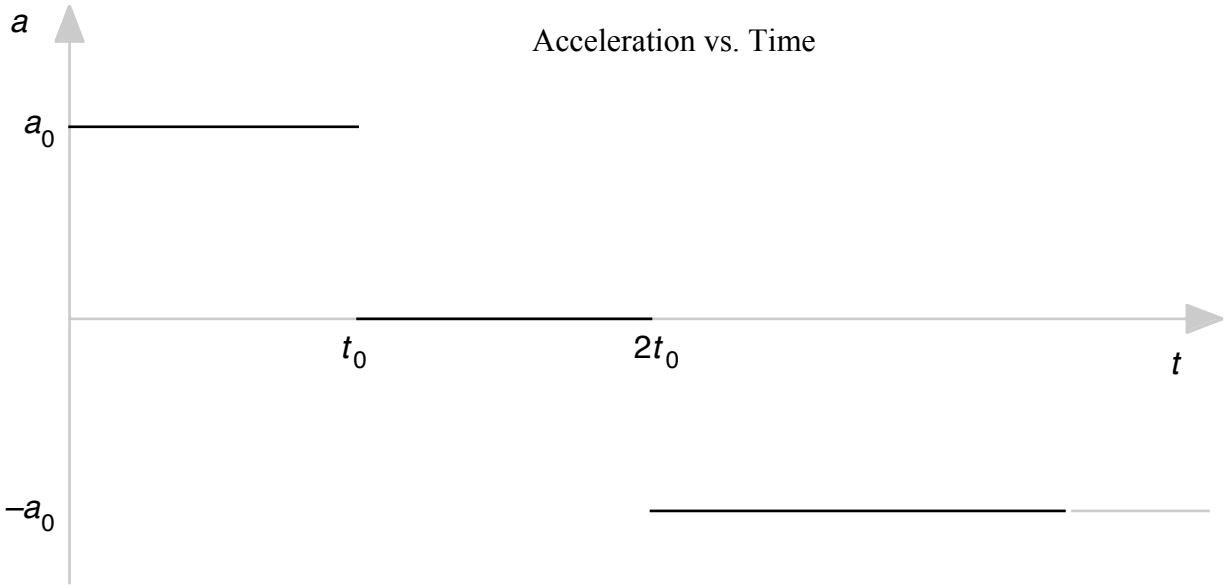
Possibly Useful Information

Gravitational field at the Earth's surface	$g = 9.8$ N / kg
Newton's gravitational constant	$G = 6.67 \times 10^{-11}$ N $\cdot$ m^2 / kg^2
Average Earth-Sun Distance	1 Astronomical Unit (A.U.) $= 1.5 \times 10^{11}$ m
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	$^1/_{12}\, ML^2$

1.



An object starts at rest at the origin at $t = 0$ and accelerates according to the graph shown above. The motion is one-dimensional.

(10) a. Sketch a graph of velocity versus time. Show and clearly label all extreme values, discontinuities, and zero crossings.

(15) b. At what time (expressed in terms of t_0) does the object return to the origin?

2. One means of attempting to detect planets orbiting other stars is to look for stellar wobble. This wobble indicates motion of the star about the star-planet center of mass. Assume the mass of the star is M, the mass of the planet αM ($\alpha << 1$), and the distance from the center of the star to the center of the planet is R. See accompanying diagram.

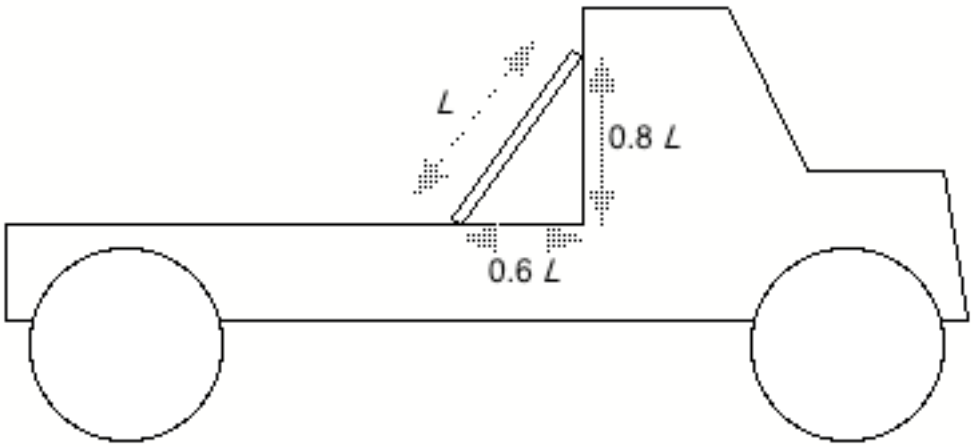
(20) a. Derive an equation for the magnitude of the star's velocity v about the star-planet center of mass in terms of α, G, M, and R. Your answer should be given to lowest order in α.

Scientists think they can detect stars with speeds v as small as 3.0 m/s.

(5) b. What is the maximum distance a planet with Earth's mass could be from a star of solar mass and still be detected by stellar wobble? Express your answer in astronomical units (A.U.).

Possibly useful information:

Mass of sun	2.0×10^{30} kg
α for Earth	3.0×10^{-6}
R for Earth	1.5×10^{11} m (= 1 A.U.)



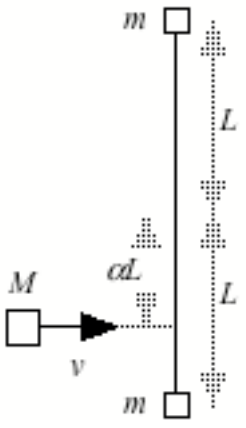
3. A uniform board of mass m and length L is placed on the back of a flatbed truck as shown in the diagram above. There is no friction between the top of the board and the vertical surface of the truck. The coefficient of static friction between the bottom of the board and the horizontal surface of the truck is $\mu_s = 0.50$. The truck always moves in the forward direction. Express your answers to the following as multiples of g.

(10) a. What is the maximum starting acceleration the truck can have if the board is not to slip or fall over?

(10) b. What is the maximum stopping acceleration the truck can have if the board is not to slip or fall over?

(5) c. For what value of stopping acceleration is the static frictional force equal to zero?

4. A dumbbell of length $2L$ is initially at rest on a horizontal surface. The accompanying diagram shows a view looking down at the surface. Both cubes at the ends of the dumbbell have mass m. The connecting rod is massless. An object with mass M and velocity v perpendicular to the rod slides across the surface and strikes the dumbbell a distance αL from its center. The collision is perfectly elastic. There is no friction between any of the objects and the surface. Assume the masses M and m can be treated as point masses. After the collision, mass M is at rest.



(15) a. Find M in terms of some or all of the quantities α, L, v, and m.

(5) b. What is M if $\alpha = 1$, i.e., M strikes m at the end of the rod?

(5) c. What is M if $\alpha = 0$, i.e., M strikes at the center of the rod?

Note: Parts (b) and (c) can be answered without first doing Part (a).