PHY 2060 Fall 2006 — Exam 1

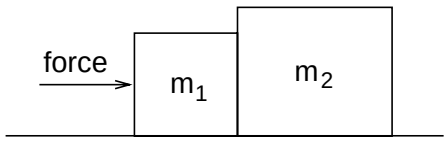
Instructions: Attempt all ten questions, each of which carries a maximum of 10 points. Write your solution below each question, continuing on the back page of the exam or on additional paper if necessary. Please try to write neatly!

You will receive credit only for knowledge and understanding that you demonstrate in your written solutions. It is in your best interest to write down something relevant for every question, even if you can't provide a complete answer. To maximize your score, you should briefly explain your reasoning and show all working. Give all final algebraic answers in terms of variables defined in the problem, g (the acceleration due to gravity near the Earth's surface), and/or c (the speed of light). For numerical problems, take $g = 10\,\mathrm{m/s^2}$ and $c = 3.0 \times 10^8\,\mathrm{m/s}$.

During this exam, you may use one formula sheet and an electronic calculator. You are not permitted (a) to consult any other books, notes, or papers, (b) to use any other electronic device, or (c) to communicate with anyone other than the proctor. In accordance with the UF Honor Code, by turning in this exam to be graded, you affirm the following pledge: *On my honor, I have neither given nor received unauthorized aid in doing this assignment.*

1. The position of a particle moving along the x axis is given by $x = a + bt - ct^2$, where a, b, and c are positive constants.
   (a) Find the velocity as a function of time.
   (b) What is the average velocity over the time interval $0 \le t \le 2$?
   (c) At what time is the particle at its rightmost point, and what is its position at that time?

2. Two blocks, of mass m_1 and m_2, lie in contact on a horizontal, frictionless table. A horizontal force applied to the leftmost block, which is m_1, gives both blocks a common acceleration a to the right.



   (a) What is the magnitude of the applied external force?
   (b) What is the magnitude of the contact force between the two blocks?

3. At the moment you pass over Gainesville at the start of a journey to Pluto (5.0 billion km away, as measured from the Earth), your spaceship's dashboard clock reads 1:00 p.m. If you travel at a constant speed of 1.0 billion km/h, what time will the clock read when you reach Pluto?

4. A 10-m-diameter Ferris wheel rotates in a vertical plane (so that its rotation axis is horizontal). Each seat can provide at most 400 N of support to its occupant before the seat breaks. Suppose that Jack (mass 35 kg) and Jill (mass 30 kg) are the only passengers, and the speed of the Ferris wheel is gradually increased from zero. At what speed, measured in revolutions per minute, will the first seat break?

   Clarification: Jack and Jill occupy different seats on the Ferris wheel.

5. A ball is thrown straight upwards, and reaches a height h above its release point. The same ball is now thrown with the same initial velocity as before, but this time at an angle of 30° above the horizontal. In both cases, air resistance can be neglected. What is the ball's maximum height above its release point on the second throw?

6. At the Solar-Neighborhood Games, competitor A (from Alpha Centauri) approaches the finishing line of the 10,000-km sprint at $0.30\,c$, as measured by an official S (from Sirius) standing beside the track. A is overtaken by entrant B (from Barnard's Star), whose speed as seen by A is $0.60\,c$. However, B doesn't win the race, because he/she/it is passed by runner C (from Chara) traveling at $0.80\,c$, as measured by S.

   (a) How fast is B traveling, as measured by S?

   (b) How fast is C traveling, as measured by B?

   Give your answers as multiples of c, not in m/s.

7. On a visit to a mall, a shopper standing on an escalator traveling at $\sqrt{2}\,\mathrm{m/s}$ at an angle of 45° above horizontal throws an empty water bottle horizontally relative to himself at a speed of 10 m/s, back in the direction of the foot of the escalator. The bottle is 4 m above the floor of the mall at the moment it is released.

   (a) How long does the bottle remain in flight before hitting the floor?

   (b) How fast is the bottle moving when it lands?

   Neglect air resistance and assume that the bottle hits no other object before reaching the floor.

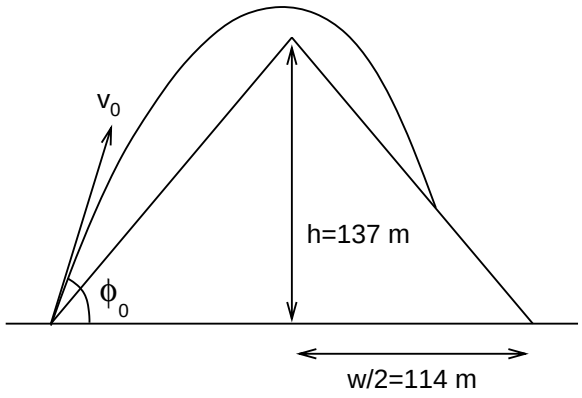
8. Overwhelmed by his Christmas Eve duties, Santa has traded in his sled for a spaceship of proper length 60 m. This spaceship is moving on a straight course past Earth at a constant speed $u = 3c/5$ when Rudolph's nose gives out a flash of red light at the front of the spaceship, and—at the same time, as measured in the spaceship's rest frame—the engines emit a flash of yellow light at the rear of the spaceship. For the purposes of this problem, treat the Earth as an inertial reference frame.

   (a) What is the spatial distance between the two flashes, as measured in the Earth's frame?

   (b) Is the answer to (a) the same as the length of the spaceship as measured in the Earth's frame? If not, what is that length?

   (c) What is the time interval between the light flashes, as measured in the Earth's frame? Which light flash occurs first: the red or the yellow?

9. On a trip to Giza, you can't resist using a slingshot to fire a pebble towards the top of the Great Pyramid. You launch the pebble at 75° above the horizontal at an initial speed of 60 m/s from a point at ground level, right at the foot of the pyramid (see figure). At what height above the ground does the pebble first make contact with the opposite face of the pyramid? Ignore air resistance.



10. A newly discovered asteroid is found to be on course for a catastrophic collision with Earth. An old Saturn V rocket is refurbished and outfitted with a nuclear warhead designed to divert the asteroid's course. At the moment the rocket is launched, the asteroid's approach speed is 15 km/s, its speed is increasing at a constant rate of $0.05\,\mathrm{m/s^2}$, and at this rate the asteroid will make impact with the Earth in exactly 10 days. If the rocket has a constant acceleration of $5\,\mathrm{m/s^2}$ for the first 20 min of its flight, after which time it maintains a constant velocity, how far from Earth will the rocket meet the asteroid?

    For the purposes of this question, assume that the rocket and the asteroid travel along the same straight line, and that all effects of gravity have been taken account in the accelerations given above. Relativistic effects are negligible.