PHY 2060 Fall 2007 — Exam 1

DO NOT TURN THE PAGE UNTIL INSTRUCTED TO DO SO

Instructions: Attempt all ten questions, each of which carries a maximum of 10 points. Write your solution below each question, continuing 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. (This may benefit you even in the case of the multiple-choice Question 1.) 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 $c = 3.0 \times 10^8\,\mathrm{m/s}$.

1. A solid sphere, released from rest just below the surface of the water in a bottomless well, begins to fall vertically downwards. The well water is completely still, apart from the disturbance created by the sphere. The only forces acting on the sphere are its weight, buoyancy, and drag. Assume that the acceleration due to gravity does not change with depth in the well.

   Place a check to the left of any/all of the following statements that is/are true:

   i. The sphere will eventually come to a halt.

   ii. The sphere's acceleration is greatest in magnitude the moment after it is released.

   iii. The sphere will undergo a constant acceleration.

   iv. If the sphere is of sufficiently low density, it may eventually halt its downward motion and then make its way back up to the surface.

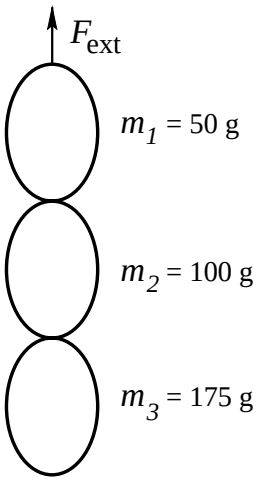
   v. The sphere will eventually approach a constant, nonzero velocity.

2. During a 2030 World Cup match, Robo-Pelé kicks a soccer ball at a speed of 225 km/h directly towards his opponents' goal, which is 25 m away. How long does it take for the ball to reach the goal?

3. A boy leaning over the edge of a balcony throws a ball vertically upwards. By the time the ball hits the ground 7.4 m below, it is moving at three times its initial speed. Find that initial speed.

4. A tracking station on Earth spots Cupid cruising directly towards Earth at a speed of $0.6c$. The tracking station also detects an arrow that Cupid has fired towards a work-obsessed physicist. The tracking station measures the arrow traveling at a speed of $0.9c$ straight towards Earth. How fast does Cupid observe the arrow to be traveling relative to himself?

5. A chain consisting of three links (numbered 1, 2, 3) is lifted vertically with a constant acceleration of 5.6 m/s^2, as shown in the figure.



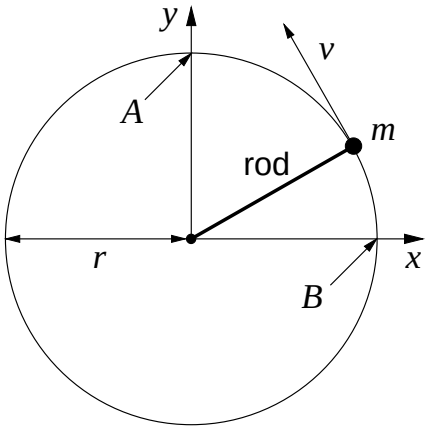
   (a) Find the magnitude of the external force acting on the top link (F_{ext} in the diagram).

   (b) Find the magnitude of the net force acting on each of the links (call them $F_{\text{net},1}$, $F_{\text{net},2}$, $F_{\text{net},3}$).

   (c) Find the magnitude of the two interlink forces (call them F_{12} and F_{23}).

6. A conveyor belt has the letters of the alphabet printed in order along its length in a repeating sequence, one letter every 3 cm. The belt moves at a constant speed of 30 cm/s in a direction so that the letters pass a fixed reference point in the order $ABCD\ldots$ (as opposed to $AZYX\ldots$). A machine drops a can from rest at a height of 80 cm above the belt. If the letter C is directly below the can at the moment of release, what letter will the can land on?

7. A point mass m is attached to one end of a massless, rigid rod. The other end of the rod is attached to a motor mounted on a benchtop. When the motor is switched on, the mass moves in a vertical plane, rotating at constant speed v in a circle of radius r. Let F_x and F_y be the horizontal and vertical components (respectively) of the force exerted by the rod on the mass. (See the coordinate axes in the figure.)

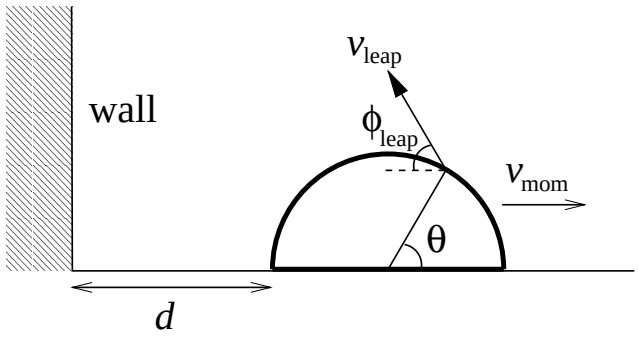


   (a) Find F_x and F_y at the moment when the mass is at the point labeled A in the figure.

   (b) Find F_x and F_y at the moment when the mass is at the point labeled B in the figure.

8. Proxima Centauri is 4.2 light years from Earth, as measured in the Earth's rest frame. (A light year is the distance light travels in a vacuum in one calendar year.) At the instant a rocket heading straight for Earth passes Proxima Centauri, the rocket's on-board computer makes an announcement that crew member Alice is exactly 20 years old. How fast must the rocket travel in the Earth's rest frame if the rocket is to make it back to Earth just as the on-board computer announces Alice's twenty-first birthday?

9. A mother spider carries her baby on her back. The mother, who had been resting quietly a distance $d = 3\,\text{cm}$ from a wall, notices someone approaching with a broom to squash her. She starts running away from the wall with a velocity $v_{\text{mom}} = 1.63$ cm/s.



The baby, realizing that doom is imminent, decides to make a break for it by jumping onto the wall. If the baby jumps 1.0 second after his mother starts running, what is the minimum leap speed v_{leap} relative to the ground that will allow him to land on the wall? Treat the mother spider as a hemisphere of radius 2.0 cm. The baby is located on the mother's surface at angle $\theta = 49°$ and leaps towards the wall at an initial angle of $\phi_{\text{leap}} = 49°$ (see figure).

10. In the Wild Western Galaxy, a rocket train is moving along a straight track at a speed v_t close to (but less than) the speed of light. Outlaw Oscar, standing at the front of the train, fires his gun (event 1). Oscar aims at Sheriff Stan, who is standing at the back of the train. The bullet misses Stan, but does knock off his hat (event 2).

    In the rest frame of the train, the length of the train is L and the bullet's speed is v_b. Take the train's velocity as observed in the rest frame of the track to be directed along the $+x$ direction.

    (a) In the rest frame of the track, what is the time interval $t_2 - t_1$ between the two events?

    (b) In the rest frame of the track, what is the spatial displacement $x_2 - x_1$ between the two events?

    (c) Is it possible for the speed $v_b < c$ of the bullet to be chosen so that, in the rest frame of the track, it knocks off Stan's hat at the same spatial location as it is fired? If so, find the speed v_b that achieves this.

    (d) Is it possible for the speed $v_b < c$ of the bullet to be chosen so that, in the rest frame of the track, it knocks off Stan's hat at the same time as it is fired? If so, find the speed v_b that achieves this.