PHY 2060 Spring 2008 — Final Exam

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), G (the gravitational constant), and/or c (the speed of light). For numerical problems, take $g = 10\,\mathrm{m/s^2}$, $G = 6.7 \times 10^{-11}\,\mathrm{Nm^2/kg^2}$, and $c = 3.0 \times 10^8\,\mathrm{m/s}$.

1. For each of the two parts of this question, place a check next to one answer only.

   (a) A projectile is fired from ground level over level ground with an initial velocity that has a vertical component of $20\,\mathrm{m/s}$ and a horizontal component of $30\,\mathrm{m/s}$. Using $g = 10\ \mathrm{m/s^2}$, the distance from launching to landing points is

   i. 40 m
   ii. 60 m
   iii. 80 m
   iv. 120 m
   v. 180 m

   (b) A certain spring elongates 9.0 mm when it is suspended vertically and a block of mass M is hung on it. The natural angular frequency of this block-spring system

   i. is 0.088 rad/s.
   ii. is 33 rad/s.
   iii. is 200 rad/s.
   iv. is 1140 rad/s.
   v. cannot be computed unless the value of M is given.

2. The coordinates x and y (in meters) of a particle as a function of time t (in seconds) are $x = 3t^2$ and $y = 16t - 4t^2$.

   (a) Find the particle's velocity and acceleration at time t.

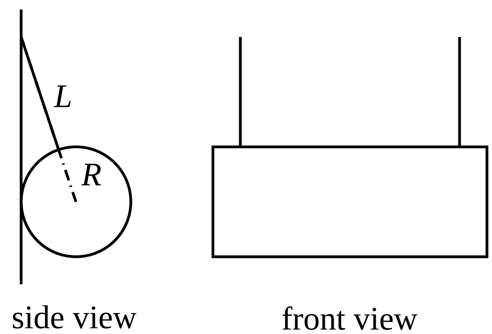
   (b) Find the particle's smallest speed.

3. The planet Mars has a mass of 6.4×10^{23} kg and a radius of 3,400 km. The first manned space expedition to Mars makes the remarkable discovery that the planet is a spherical shell only 1 km thick. Find both (i) the force in newtons on the expedition's 16,000-kg spaceship and (ii) the binding energy in joules of the Mars-spaceship system, when the spaceship is located ...

   (a) 500 km from the center of Mars.

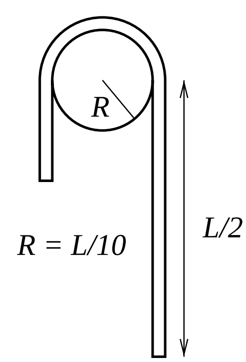
   (b) 5,000 km from the center of Mars.

4. A thin cylindrical pipe of mass M and radius R is held by a pair of ideal ropes in a horizontal orientation against a frictionless wall, as shown in the pair of side views below. The pipe walls are of uniform thickness. Each of the ropes is of length L and is attached to the pipe in such a way that the rope points through the pipe's cylindrical axis. Find the tension in each rope and the magnitude of the force exerted by the wall on the pipe.



5. A ladder of length L and negligible mass leans against a frictionless wall. The angle between the ladder and the horizontal ground is θ. The coefficient of static friction between the ladder and the ground is μ_s. A person of mass m starts slowly up the ladder. What fraction of the way up the ladder can the person reach before the ladder becomes unstable?

6. A pulley consists of a uniform disk of mass m and radius $L/10$ that can rotate freely about a horizontal, frictionless axle. A uniform rope of length L and mass M is hung over the pulley, with half the rope's length dangling straight down on one side of the pulley, and the rest of the rope either in contact with the pulley or hanging straight down on the other side, as shown in the diagram. This system is released from rest. How fast will the bottom end of the rope be traveling when it has traveled a distance $L/10$ (without hitting any nearby objects)? Assume that the rope does not slip around the perimeter of the pulley.



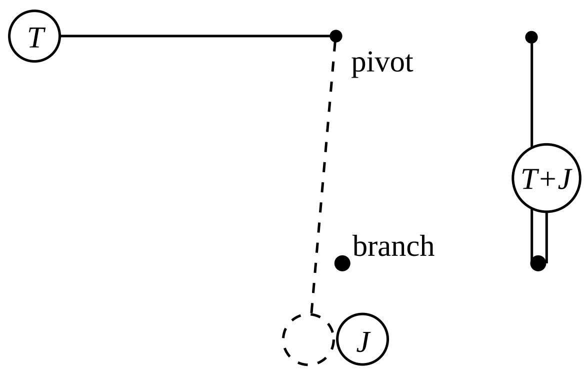
7. Alice measures event B to occur $2.0\,\mu\text{s}$ after event A and at a displacement $\Delta x = 1.0\,\text{km}$ from A. Alice also observes Bob to be traveling at a constant velocity along her x axis. Bob measures events A and B to be simultaneous.

   (a) Is it possible for event A to have caused event B?

   (b) How fast must Bob be moving in Alice's frame?

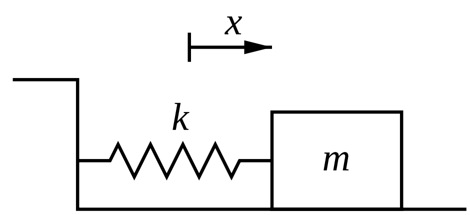
   (c) Suppose that Alice measures event C to occur $2.0\,\mu\text{s}$ after event A. What is the smallest distance $|\Delta x|$ by which events A and C must be separated for it to be possible for any inertial observer to measure the events to occur simultaneously?

8. Tarzan, sitting on top of a large termite mound, sees Jane in mortal danger standing on the jungle floor. Tarzan swings in a quarter circle on the end of an ideal (massless, unstretchable) vine of length 15.0 m and grabs Jane, as shown in the left-hand diagram. Unfortunately, Tarzan has failed to spot a low-lying branch located 13.0 m directly below Tarzan's pivot point and 2.0 m directly above where Jane was initially standing. The vine catches on the branch, causing Tarzan and Jane to rise to the position shown in the right-hand diagram. Given that Tarzan has a mass of 80 kg and Jane's mass is 50 kg, find the tension in the vine at the moment shown in the right-hand figure. (Treat Tarzan and Jane as point masses.)



9. A pendulum consists of a thin, uniform rod of mass M and length L, to which a small ball of mass $2M$ is firmly attached. The rod is pivoted freely at one end. How far from the pivot should the ball be attached so that the pendulum has the shortest possible period?

10. A mass m sits on a horizontal surface, connected to a fixed point by a horizontal, ideal spring of constant k, as shown in the diagram. The coefficient of kinetic friction between the mass and the surface is μ_k. The mass is released from rest at a point where the spring is extension is $x_0 > 0$. The spring force is sufficient to overcome static friction, so the spring starts in motion.



(a) Find the spring displacement x_1 at the first time the mass comes to rest.

(b) Assuming that the spring force at $x = x_1$ is sufficient to overcome static friction, find the spring displacement x_2 at the second time the mass comes to rest.