# PHY 2060 Spring 2006 — Exam 3

**Instructions:** Attempt all ten questions, each of which carries a maximum of 10 points. You will receive credit only for knowledge and understanding that you demonstrate in your written solutions. To maximize your score, you should briefly explain your reasoning and show all working. Give all final answers in terms of variables defined in the problem, and/or either of the following quantities: $G$ (the gravitational constant) and $g$ (the acceleration due to gravity near the Earth's surface). For numerical problems, take $G = 7 \times 10^{-11}\,\text{N·m}^2/\text{kg}^2$ and $g = 10\,\text{m/s}^2$. Please try to write neatly!

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.*

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1. A piano of mass $300\,\text{kg}$ rolls without friction down a ramp from the back of a truck and then onto a horizontal floor. The piano is moving at a constant speed of $2.5\,\text{m/s}$ across the floor when you begin applying a horizontal force $F = 200\,\text{N}$ to it, as shown in the figure. The piano travels $3\,\text{m}$ further across the floor before hitting a wall.

   (a) How much work do you perform on the piano during this motion?

   (b) How fast is the piano moving by the time it hits the wall?
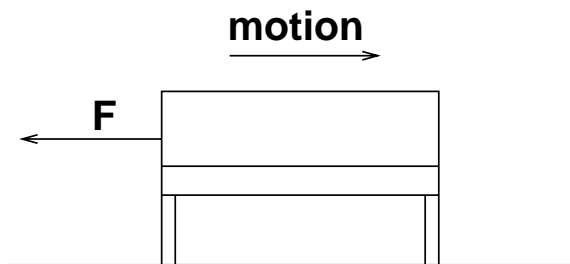
   

2. Three dense spheres, each of mass $m$, are arranged at the corners of an equilateral triangle of sides $l$. The spheres are stationary, and no other masses are close enough to be relevant to the problem.

   (a) Find the magnitude of the net gravitational force on any one of the spheres due to the other two spheres.

   (b) How much work must be done by an outside force to assemble this configuration, starting with the three spheres at rest at infinite separation from one another?

3. A mass $m$ is attached to two ideal springs, each of which has a natural (unstretched) length $L$ and a spring constant $k$. The other ends of the springs are attached to two rigid supports, the upper support located a distance $2L$ vertically above the lower support. Starting with the mass hanging at rest between the two supports, what minimum work must you do to lift the mass to the point mid-way between the supports?

**L**

**L**
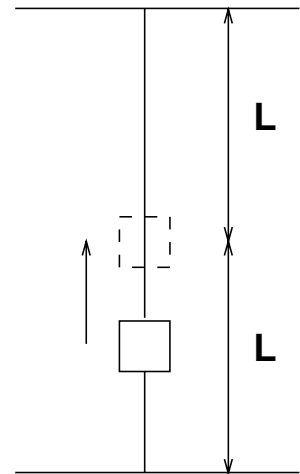
4. A uniform meter stick of mass $150\,\mathrm{g}$ can rotate freely in a horizontal plane about a pivot located distance $20\,\mathrm{cm}$ from one end. A bullet of mass $10\,\mathrm{g}$, traveling at $450\,\mathrm{m/s}$ at right angles to the stick, embeds itself at the stick's midpoint. What is the resulting angular velocity of the meter stick?

5. Real springs exhibit deviations from Hooke's law at large extensions. Suppose that such a spring obeys the force-extension relation $F(x) = -kx + \alpha x^2$ for $x \geq 0$, where $k$ and $\alpha$ are both positive.

   (a) Find the "ultimate extension" of the spring, i.e., the extension at which the spring tension reaches its maximum value: the "ultimate tension." (If an external force exceeding the ultimate tension is applied, the spring will continue stretching until it breaks.)

   (b) What is the total work that must be done by an outside force to stretch the spring from its natural length to its ultimate extension?

6. A uniform circular disk of mass $M$ and radius $R$ can swing freely in a vertical plane about a horizontal axis passing through a point on its circumference. The disk is held with its center at the same height as the axis (as shown in the figure), and is then released from rest. What is the disk's maximum angular velocity during its subsequent motion?

**axis (out of page)**
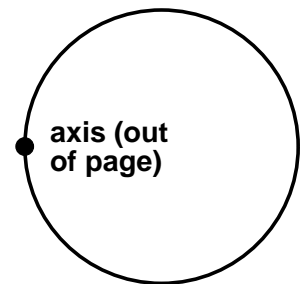
7. The planet Ork is a uniform sphere of radius $R$ and mass $M$. Find the gravitational force on a small object of mass $m$ located ...

   (a) a distance $d$ above the surface of Ork;

   (b) a distance $d$ below the surface of Ork.

8. Tarzan and Jane visit a water hole. Tarzan, who can't read the warning signs, strays too close to the water and is about to be swallowed by a very large hippopotamus. Jane (mass 50 kg) swings on a 10-m-long vine (of negligible mass) to save Tarzan (mass 80 kg). Jane starts from rest with her center of mass 5 m above the ground, grabs Tarzan just as she gets to 1 m above ground level, and carries him out of harm's way (see figure).

   (a) Find the change in internal energy of the universe during this daring rescue.

   (b) Suppose that Jane grabs the hippopotamus instead (all other details being the same). Estimate the change in internal energy of the universe under this alternative scenario.
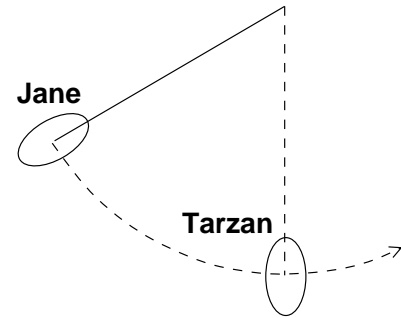
9. A uniform, solid sphere of mass $M$ and radius $R$ is released from rest on plane inclined at angle $\theta$ to the horizontal. The coefficients of static and kinetic friction between the sphere and the plane are $\mu_s$ and $\mu_k$, respectively. What is the sphere's speed after it has rolled without slipping a distance $d$ measured parallel to the incline plane?

10. A block of mass $m$ is released from height $h$ on a curved, frictionless ramp. At the foot of the ramp, the block continues sliding over a horizontal surface that has a coefficient of kinetic friction $\mu_k$. After sliding a distance $d$, the block strikes the end of a (relaxed) spring of constant $k$, and comes to an instantaneous halt after traveling a further distance $c$.

   (a) Find an expression for $c$.

   (b) What is the minimum value of $h$ that allows the block to recoil back all the way to the foot of the ramp? (Eliminate the variable $c$ from your final answer.)