

**PHY 2060 Fall 2005 — Exam 3**

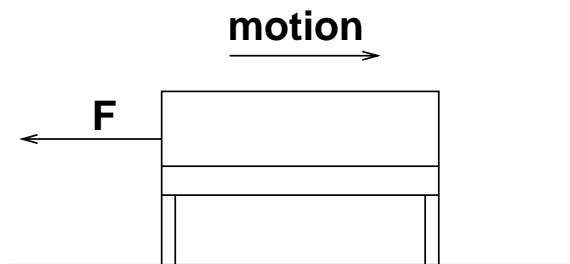
**Instructions:** Attempt all ten questions, each of which carries a maximum of 10 points. You will receive credit only for knowledge and understanding that you demonstrate in your written solutions. To maximize your score, you should briefly explain your reasoning and show all working. Give all final answers in terms of variables defined in the problem, and/or any of the following quantities:  $G$  (the gravitational constant),  $g$  (the acceleration due to gravity near the Earth's surface),  $M_E$ ,  $R_E$ , and  $T_E$  (the Earth's mass, radius, and rotational period, respectively). Please try to write neatly!

During this exam, you may use up to three formula sheets. You are not permitted to consult any other books, notes, or papers, to use calculators or any other electronic device, or 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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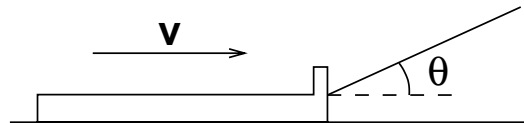
1. A piano of mass  $m$  rolls without friction down a ramp from the back of a truck and then onto a horizontal floor. The piano is moving at a constant speed  $v_0$  across the floor when you begin applying a horizontal force  $F$  to it, as shown in the figure. The piano travels a further distance  $L$  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?



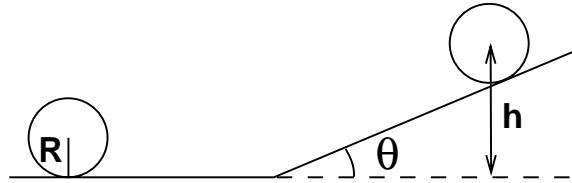
2. A dart of mass  $m$  traveling horizontally at a speed  $v$  embeds itself into a target of mass  $M$  hanging from an ideal string of length  $l$ . To what height  $h$  above its initial position does the target rise? (You may assume that  $h < 2l$ .)

3. A girl pulls a sled of mass  $m$  at a constant speed  $v$  over flat ground by pulling on an ideal rope that makes an angle  $\theta$  to the horizontal. The coefficient of kinetic friction between the sled and the ground is  $\mu_k$ .



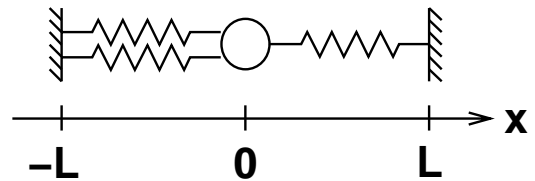
- (a) Find the normal force exerted by the ground on the sled.
- (b) Find the force exerted by the girl on the sled (via the rope).
- (c) Find the work done by the girl on the sled during the time the sled moves a distance  $d$ .

4. A uniform sphere of mass  $M$  and radius  $R$  rolls without slipping at a uniform center-of-mass speed  $v$  across a horizontal surface until it comes to a slope inclined at angle  $\theta$  to the horizontal. The sphere travels up the slope until its center of mass reaches a maximum height  $h$  above the horizontal surface.



- (a) Find  $h$ , assuming that the sphere rolls without slipping on the slope.  
 (b) Find  $h$ , assuming instead that the slope is frictionless.
5. A particle of mass  $m$  is connected as shown in the figure to three ideal springs, each having force constant  $k$  and natural length  $L$ . The particle, which rests on a frictionless tabletop, is displaced by an external force to the point  $x = -d$  and then released from rest.

- (a) Find the net horizontal force on the particle as a function of its position  $x$ .  
 (b) Find the particle's speed as a function of its position  $x$ .

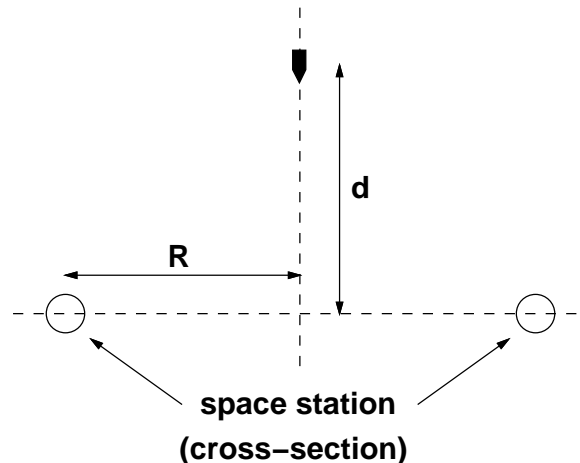


6. A space station of mass  $M$  takes the form of a narrow tube bent into a circular ring of radius  $R$  (rather like a bicycle inner tube). The radius of the tube is much smaller than  $R$  and can be neglected for the purposes of this problem. A shuttle of mass  $m$  approaches the space station along the latter's axis of rotational symmetry.

- (a) What is the gravitational force (magnitude and direction) on the shuttle due to the space station when the shuttle is a distance  $d$  from the plane of the space station?

Hint: Consider the force due to a small piece of the ring. Add up these contributions, taking advantage of the symmetry of the problem.

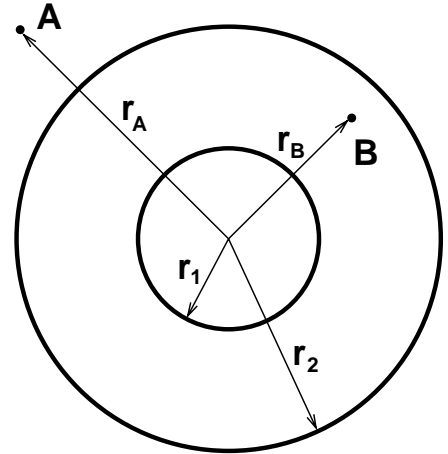
- (b) At the same moment, what is the gravitational force (magnitude and direction) on the space station due to the shuttle?



7. A probe of mass  $m$  is to be launched from the Earth's surface into deep space. Find the escape velocity of the probe if it is launched . . .
- from the north pole.
  - from the equator, heading due east.
  - from the equator, heading due west.

Ignore all gravitational effects due to astronomical objects other than the Earth.

8. An artificial planet consists of two concentric shells: the inner shell has mass  $m_1$  and radius  $r_1$ , while the outer shell has mass  $m_2$  and radius  $r_2$ . Each shell is of uniform thickness and density.



- Find the gravitational force on a particle of mass  $m$  located at point  $A$ .
  - Find the gravitational force on a particle of mass  $m$  located at point  $B$ .
  - Find the external work done in bringing a particle of mass  $m$  from infinity to point  $B$  (through a tiny hole in the outer shell).
9. A gymnast of mass  $m$  crouches with his center of mass at height  $h_0$  above the floor. He now springs vertically upwards by pushing down on the ground with a constant force  $F$  in addition to his weight, so that the normal force exerted by the ground has a magnitude  $F + mg$ .
- What is the gymnast's speed at the moment when his center of mass is at height  $h$  above the floor? Assume that the gymnast is still in contact with the floor.
  - At this moment, by how much has the gymnast's internal energy changed from its value at the start of the leap?
10. A block (mass  $m_1$ ) sits on a second block (mass  $m_2$ ), which in turn sits on a horizontal, frictionless table. The coefficient of kinetic friction between the two blocks is  $\mu_k$ . This system is initially at rest. Then a constant horizontal force  $F$  is applied to the lower block, causing the lower block to move with respect both to the table and to the upper block. (The upper block remains on top of the lower block the whole time.)
- What is the magnitude of the frictional force acting between the blocks?
  - What is the acceleration of the lower block?
  - What is the change in internal energy of the two blocks during the period that the lower block is displaced a distance  $d$  from its initial position?