Physics 151 Roster No.:__________________________
Due: Monday, April 17, 2006

Score:______________________________

Take-Home Midterm Exam #3, Part A

NO exam time limit. Calculator required. All books and notes are allowed, and you may obtain help from others. Complete all of Part A ***AND*** Part B.

For multiple-choice questions, circle the letter of the one best answer (unless more than one answer is asked for). For fill-in-the-blank and multiple-choice questions, do you NOT need to show your work.

Show your work on all free-response questions. Be sure to use **proper units** and **significant figures** in your final answers.

Ignore friction and air resistance in all problems, unless told otherwise.

<u>*Physical constants:*</u> It's an open-book test, so you can look them up in your textbook!
<u>*Useful conversions:*</u> It's an open-book test, so you can look them up in your textbook!

1. (4 pts.) **Convert** the following quantities into the given units. Fill in the blanks. (You do NOT need to show your work.) Use *scientific notation* where appropriate (very large or very small values), and express all final values to *THREE significant figures*.

a. 4.55×10^{-7} THz = ___________________ MHz

b. 3.00×10^{10} cm/s = __________________ mi/h (miles/hour)

c. 2700 rpm = ________________________ rad/s ("rpm" = rev/min)

d. 27,400 g·mm^2 = ____________________ kg·m^2

2. A 57-g tennis ball moving to the right at 51 m/s is hit by a tennis racquet. Immediately afterward, the ball travels to the left at 35 m/s.

a. (2 pts.) What is the total **impulse** that the ball receives from the racquet (in MKS units)? ________________

b. (1 pt.) If the ball is in contact with the racquet for a total of 15 ms, what is the **average force** that the racquet exerts on the ball (in MKS units)? ________________

3. Three friends enjoy a group hug, at rest, in the middle of a frictionless ice-skating rink. When they are done, they simultaneously push themselves away from each other, resulting in the following motion:

Friend *A* (50.0 kg) moves away with a velocity of 1.80 m/s at 0.0˚.
Friend *B* (58.0 kg) moves away with a velocity of 2.20 m/s at 120.0˚.
Friend *C* (68.0 kg) moves away with a velocity of v_C at θ_C.

In **MKS units**…

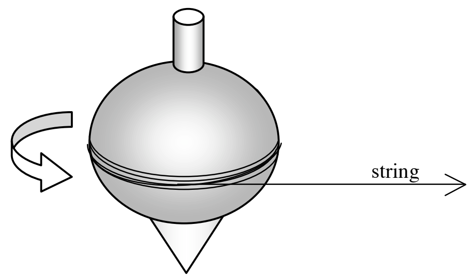
a. (1 pt.) What is the ***total*** **momentum** of all three friends after they have separated? ________________

b. (3 pts.) What are the **magnitude and direction** of *C*'s final **velocity**? ________________at _______________˚.

c. (1 pt.) Which one of the three friends received the **greatest impulse** from the "explosion"? _____________

4. a. (3 pts.) In MKS units, what is the **Sun's angular momentum** as it spins about its own axis? _______________
(Assume that our Sun is a solid sphere that completes one rotation every 28.0 days. Additional astronomical data are located in the rear endpages of Walker.)

b. (3 pts.) In MKS units, what is the **angular momentum of Jupiter** as it orbits the Sun? _______________
(You may assume that Jupiter is a "point mass" orbiting in uniform circular motion. All necessary astronomical data are located in Appendix C of Walker, p. A-12.)

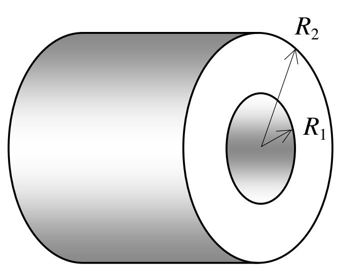


5. A string is wound around the outer edge of a toy top (radius 3.5 cm). When the string is pulled with a constant acceleration, the top "spins up" from rest to an angular speed of 66 rad/s during a period of 2.5 s. (The toy's center and bottom remain stationary: as the string is pulled, the toy rotates, but it does not translate.)

a. (2 pts.) What is the **linear acceleration** of the string (in MKS units)? _______________

b. (2 pts.) **How many revolutions** does the toy complete during the 2.5 s of acceleration? _______________

c. (1 pt.) On the picture of the toy top above, **draw** a vector representing the **vector direction of** ω.



6. Suppose you have a cylinder with a partially-hollow interior: an inner radius R_1 and outer radius R_2. When rotating about its axis of symmetry, the moment of inertia of this partially-hollow cylinder is:

$$I = M\,\frac{(R_1^2 + R_2^2)}{2}$$

a. (3 pts.) Suppose the object rolls *without slipping* down a 0.75-m-high ramp. When it gets to the bottom, it has a linear speed of 3.0 m/s. If the partially-hollow cylinder has a mass of 2.0 kg and an outer radius $R_2 = 0.10$ m,

calculate its **inner radius, R_1**: _______________

b. (1 pt.) If you were to release a partially-hollow cylinder right next to a *solid* cylinder, which one would accelerate down the ramp **faster**? Both of their masses and outer radii are identical.

A. the solid cylinder
B. the partially-hollow cylinder
C. both would be the same
D. cannot determine with information given

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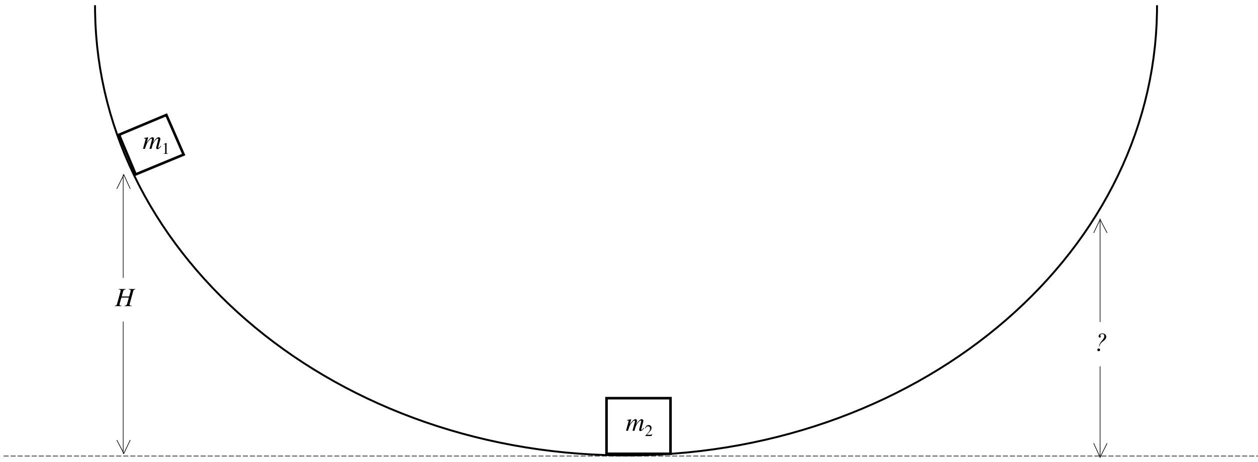
Take-Home Midterm Exam #3, Part B



1. Two *unequal* masses m_1 and m_2 are located in a large, frictionless bowl, and both start at rest. Mass m_1 is released at height H and slides to the bottom, where it collides with mass m_2.

(9 pts.) For parts (a) and (b) of this question, your answers will be algebraic expressions. You may solve parts (a) and (b) in whichever order you wish.

- Express each final answer ***ONLY*** in terms of m_1, m_2, H, g, and any necessary mathematical constants.
- Show all steps of your derivation.
- ***Simplify*** each final answer to its most compact algebraic form.

a. If the two masses *stick together* in the collision at the bottom of the bowl, find the amount of **kinetic energy lost in the collision**.
b. If they then slide together up the right-hand side of the bowl, find **the maximum height that the two masses reach** before sliding back down.

1. *continued*:

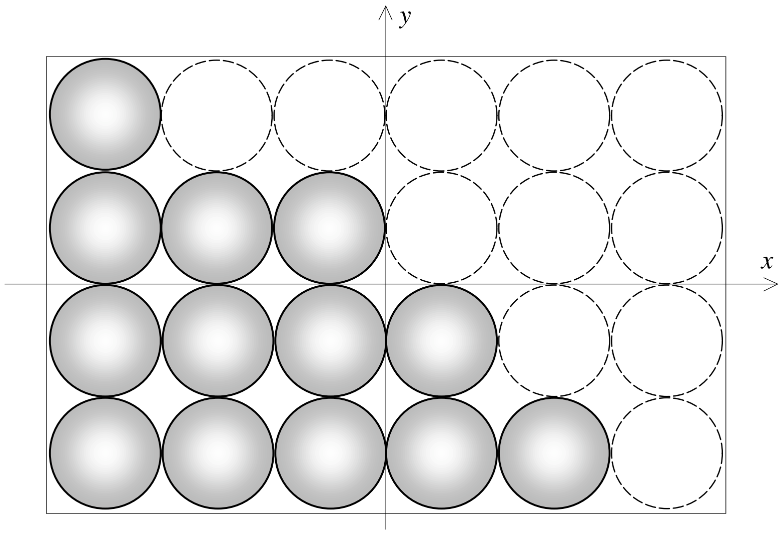
INSTEAD of sticking together, suppose that m_1 and m_2 collide at the bottom of the bowl *perfectly elastically*. This applies both to parts (c) and (d):

c. (1 pt) Which **one** of the following statements then becomes **TRUE**?

A. The total K of all masses before collision is *less than* the total K of all masses after collision.
B. The total K of all masses before collision is *the same as* the total K of all masses after collision.
C. The total K of all masses before collision is *greater than* the total K of all masses after collision.
D. Net ΔK of all masses in the perfectly-elastic case is the same as in the stuck-together case.

d. (1 pt.) Immediately after the collision, suppose the velocity of m_1 rebounds *to the left*. Which **ONE** of the following must be true about the relationship between the two **masses**?

A. $m_1 < \frac{1}{2}m_2$
B. $m_1 < m_2$
C. $m_1 < 2m_2$
D. $m_1 > \frac{1}{2}m_2$
E. $m_1 > m_2$
F. $m_1 > 2m_2$



2. A four-by-six egg carton is partially occupied (13 shaded spaces) and partially empty (11 dashed spaces), as shown in the top-view above. Each egg has an identical mass of 75 g, uniformly distributed within each egg, and each circular egg-space measures 5.0 cm in *diameter*. The mass of the tray itself is negligibly small.

a. (6 pts.) To impress your friends in the kitchen, you want to **balance** the tray of eggs on one finger. Defining the origin to be at the very center of the tray (as shown on the diagram above), beneath **what (*x*, *y*) location** should you position your finger? Give your answer in **centimeters**. Show your work clearly and completely.

2. ***continued:***

b. (4 pts.) Suppose that you position the tray of eggs so that it rests on top of a long narrow fulcrum (like a knife-edge) exactly beneath the *y*-axis in the diagram above. Immediately *after* you release the tray, calculate the **net torque** on the tray due to the weight of the eggs, in **MKS units**. (Again, assume that the mass of the tray itself is negligibly small.) Use the *y*-axis in the diagram as the axis of rotation (the "pivot"). Show your work clearly and completely.

c. (1 pt.) In the moments just after you release the egg tray as described in part (b), the tray will do which **ONE** of the following?

A. remain at rest
B. rotate about the *y*-axis at constant angular speed
C. rotate about the *y*-axis with increasing angular speed

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d. (1 pt.) The egg tray exhibits **greatest moment of inertia** when rotated…

A. about the *x*-axis
B. about the *y*-axis