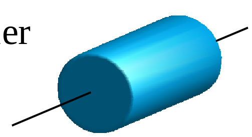
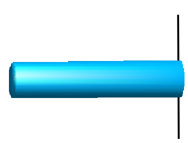
PHYSICS 131 EXAM 3 16 November 2000

INSTRUCTIONS: Write your name on the front of the blue exam booklet. The exam is closed book, and you may have only a pen/pencil and a calculator (no stored equations or programs and no graphing). Show all of your work in the blue book. For problems II−V, an answer alone is worth very little credit, even if it is correct − so show how you get it.

Suggestions: Draw a diagram when possible, circle or box your final answers, and cross out parts which you do not want us to consider.

Solid cylinder about axis $I = 1/2\ MR^2$





Thin rod about perpendicular axis through one end $I = 1/3\ ML^2$

In all problems neglect the effects of air resistance unless explicitly stated.

I. Multiple Choice Questions (4 points each). Read each question carefully. Write the SINGLE correct answer in the grid given inside your blue book. No explanation is required, and no partial credit will be given.

1. Two masses M and $5M$ rest on a horizontal frictionless table with a compressed spring of negligible mass between them. When the spring is released, the energy of the spring is shared between the two masses in such a way that

- A.) M gets 3/5 of the energy.
- B.) M gets 1/6 of the energy.
- C.) M gets 1/5 of the energy.
- D.) M gets 4/5 of the energy.
- E.) none of the above.

2. The Weekly World News often reports evidence of a communist plot to spoil the earth's orbit which involves the entire population of China jumping up and down at the same instant. The publishers give a date and time and urge patriotic westerners to "counter−jump" at the same time to stop this evil plot. Suppose the entire population of China actually jumps in unison to a pre−arranged signal. While all of the chinese are in the air, does the earth gain momentum in the opposite direction?

- A.) No; the inertial mass of the Earth is so large that the planet's change in motion is imperceptible.
- B.) Yes; because of its much larger inertial mass, however, the change in momentum of the Earth is much less than that of all of the jumping people.
- C.) Yes; Earth recoils, like a rifle firing a bullet, with a change in momentum equal to and opposite that of the people
- D.) It depends.

3. While the Chinese are in the air, they are attracted back to the earth by the force of gravity. Just before they hit the ground again, what can you say about the Earth's momentum (take the direction that the Chinese have just jumped to be "up")?

- A.) It's in the downward direction and has a magnitude smaller than the momentum of all of the Chinese.
- B.) It's in the upward direction and has magnitude smaller than the momentum of the Chinese.
- C.) It's in the upward direction and has magnitude equal to the momentum of the Chinese.
- D.) It's in the downward direction and has magnitude equal to the momentum of the Chinese.
- E.) The earth has negligible momentum.

4. In class, we had a lecture demonstration where your professor got extremely dizzy spinning around on a platform holding weights at arm's length, then bringing them in closer to the axis of rotation to demonstrate conservation of angular momentum. What would have happened if he had dropped the weights on the floor with his arms outstretched instead of bringing them in close to his chest?

A.) His angular velocity would have decreased.
B.) His angular velocity would have remained the same.
C.) His angular velocity would have increased.
D.) His angular velocity would have increased as the angular velocity of the masses decreased.
E.) His angular velocity would have decreased as the angular velocity of the masses increased.

5. If all of the objects shown below have the same mass, which of them has the largest moment of inertia about the axis indicated?

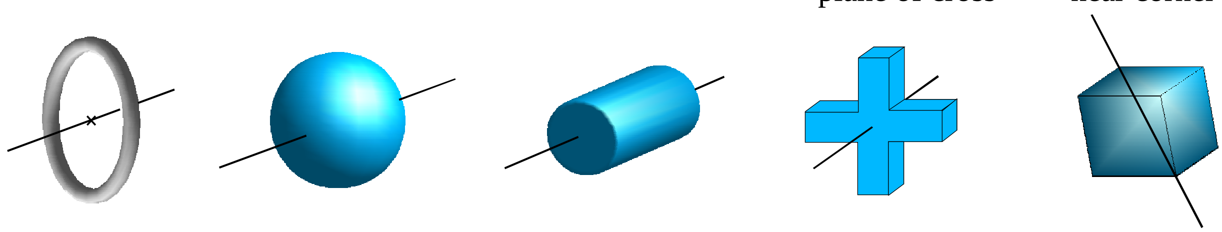
A.) Axis normal to plane of ring

B.) Axis is sphere diameter

C.) Axis is central axis of cylinder

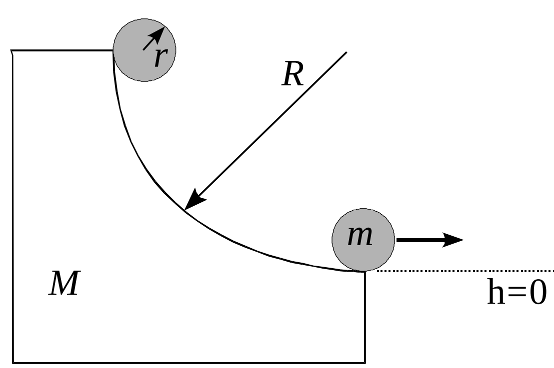
D.) Axis is normal to plane of cross

E.) Axis runs from far to near corner



Problems. (20 points each) Write the complete solutions in your blue book. Remember that no partial credit will be given for an answer with no supporting work.

II. A cylinder of mass *m* and radius *r* rolls without slipping down the curved face of a block of mass *M*. The block sits on a frictionless surface, and both objects are at rest to begin with. The curved portion of the block is a quarter−circle in cross section, where the radius of the inscribed circle is *R*.



A.) Is any component of momentum conserved in this case? Why or why not?

B.) Choosing the zero of your gravitational potential energy to be the lower edge of the curved block face (as shown in the diagram), write the total energy of the block and cylinder before and after the cylinder has rolled.

C.) Find the final velocities of the cylinder and the block.

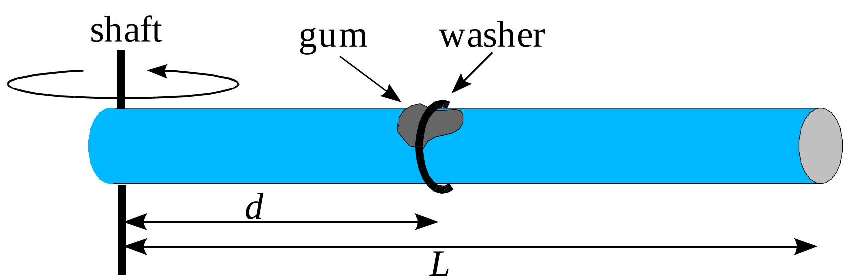
III. A steel washer is fitted around a metal rod of mass M and length L. For the purpose of this problem, treat the washer as a point mass of mass m. The washer is held in place by some old chewing gum which has lost much of its stickiness − we will approximate this as providing a frictional force with a coefficient of static friction, μ_s. As shown, the rod is attatched to a drive shaft at one end and is rotated about the shaft, and the chewing gum is at a distance d from the shaft (assume the gum has neligible mass). The rod starts from rest (ω=0) and is subject to a constant angular acceleration.

A.) Draw a free−body diagram for the washer.

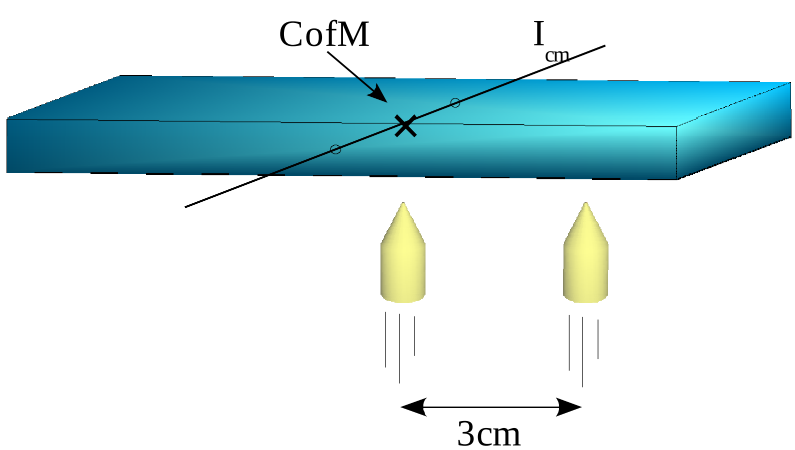
B.) What is the condition that the washer breaks free of the chewing gum?

C.) Find the angular velocity at which the washer becomes unstuck.

D.) How much work is done on the system by the drive shaft up to the point when the washer flies off?



IV. A bullet is fired upward into the bottom of a wooden block. Assume the bullet's mass is 100 g, its initial velocity is 300 m/s, and the mass of the block is 5.9 kg. The moment of inertia I_{cm} of the block about an axis through its center of mass is 0.005 kg m^2. In any case, the bullet stops in the block due to the large frictional forces.



Two cases are tried: first, the bullet is fired directly up into the center of the block.

A.) Find the velocity of the block and bullet immediately after the collision.
B.) Find the maximum height that the center of mass of the block attains.

Second, the bullet is fired 3 cm to the right of the center of the block. When working the following parts, ignore the effects of the bullet's mass on the moment of inertia and the position of the center of mass of the system.

C.) Find the velocity of the block and bullet immediately after the collision
D.) Find the maximum height that the center of mass of the block attains.

E.) What is the difference between the energy lost to friction in case 2 compared with case 1? Where does this energy go, and what must be true about the relative depths of the holes in the wooden blocks in the two cases?

V. In a nuclear reactor, neutrons are produced when a Uranium atom splits. These neutrons are moving at about 10^7 m/s and must be slowed down to about 10^3 m/s before they can catalyze the splitting of another Uranium nucleus. They are slowed down by being passed through a *moderator*, which is another solid or liquid material.

A.) If a neutron (mass m_N) collides elastically with a light nucleus such as deuterium (mass $3m_N$) which is initially at rest, calculate the final speed of the neutron (after the collision) in terms of m_N and the initial velocity. (Hint: eliminate the velocity of the recoiling nucleus from your equations in order to get v_f in terms of v_i.)
B.) What is the ratio of the neutron's final kinetic energy to its initial kinetic energy?
C.) How does this change if a material such as graphite (carbon, mass = 12 m_N) is used as the moderator?