University of California at Berkeley
Department of Physics
Physics 7A, Spring 1999

Second Midterm, section 3
April 13, 1999 12:30PM

You will be given 80 minutes to work this exam. No books are allowed, but you may use a handwritten note sheet no larger than an 8 1/2 by 11 sheet of paper. Your description of the physics involved in a problem is worth significantly more than any numerical answer. Show all work, and take particular care to explain what you are doing. Write your answers directly on the exam, and if you have to use the back of a sheet make sure to put a note on the front. Do not use a blue book or scratch paper.

sin 45° = 0.707, cos 45° = 0.707, sin 30° = 0.500, cos 30° = 0.866
Rotational Inertias for radius R or length L:

uniform sphere about axis: $(2/5)MR^2$ spherical shell about axis: $(2/3)MR^2$
disk about axis: $(1/2)MR^2$ hoop about axis: MR^2
rod about perpendicular at midpoint: $ML^2/12$ rod about perpendicular at end: $ML^2/3$

$$\sum \vec{F} = \frac{d\vec{P}}{dt} \qquad \sum \vec{\tau} = \frac{d\vec{L}}{dt} \qquad v_{2f} = \left(\frac{2m_1}{m_1 + m_2}\right) v_{1i} + \left(\frac{m_2 - m_1}{m_1 + m_2}\right) v_{2i}$$

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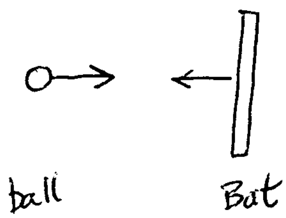
Read the problems carefully.
Try to do all the problems.
If you get stuck, go on to the next problem.
Don't give up! Try to remain relaxed and work steadily.

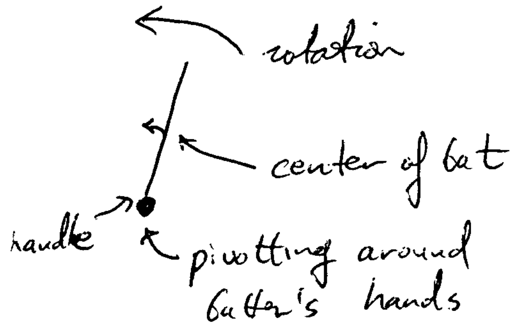
1) (30 points) Hitting a baseball

We can model a baseball bat as a uniform bar of length 1m, mass 1 kg, pivoted about one end. The ball has mass 0.2 kg. We're going to work our way up to a "realistic" model of a bat hitting a ball, but each part below should be considered separately. In all cases, the bat and ball are moving in the plane of the sheet of paper before and after the collision. Ignore the effects of gravity, air resistance, the roar of the crowd, and the high cost of hot dogs. *Make sure you explain your reasoning* – that is most of the credit.

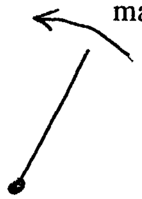
a) Consider the bat and ball colliding as shown in the drawing below. Both are moving in a straight line, and neither is rotating. The bat is moving at 10 m/s, and the ball is moving at 50 m/sec. They collide completely elastically. The ball hits the exact center of the bat. What are their velocities (magnitude and direction) after the collision?



b) Instead of the linear motion of part (a), a baseball bat is swung in a circle as shown below. If the batter swings the bat such that the center of the bat is moving at 10 m/s, what's its angular velocity? What's the linear velocity of the tip of the bat? What's the linear velocity of the handle?

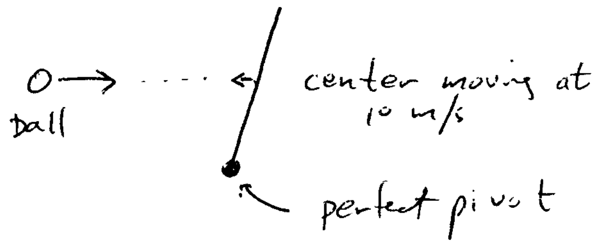


c) To swing the bat as described in part (b), the batter has to exert a force on it. At the instant shown in the drawing below, in what direction is this force? What's its magnitude?

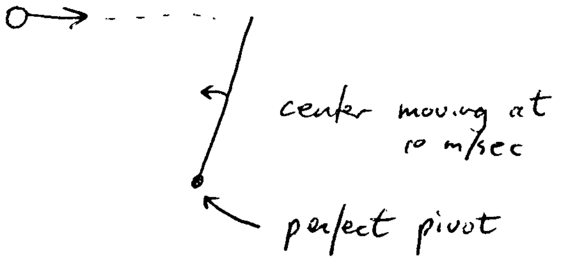


d) To start the bat moving from a stationary position (but still in the plane of the paper), does the batter need to exert a torque on it? If so, in which direction? To keep a moving bat moving at a constant rotational velocity, does the batter need to exert a torque on it? If so, in which direction?

e) The batter swings the bat such that its center is moving at 10 m/s, and so that the ball hits the center while moving at 50 m/sec. The collision is so fast that the batter can't exert any significant torque during it, so assume that the batter acts like a perfect pivot (see drawing). What are the motions of the ball and bat after the collision? Make sure directions are clear.



f) The batter swings the bat such that its center is moving at 10 m/s, and so that the ball hits the end while moving at 50 m/sec. The collision is so fast that the batter can't exert any significant torque during it, so assume that the batter acts like a perfect pivot (see drawing; this is just like part (e) *except* where the ball hits). What are the motions of the ball and bat after the collision? Make sure directions are clear.

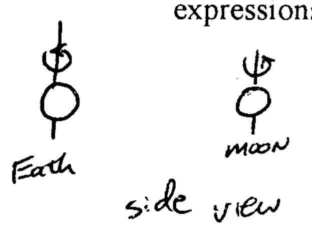


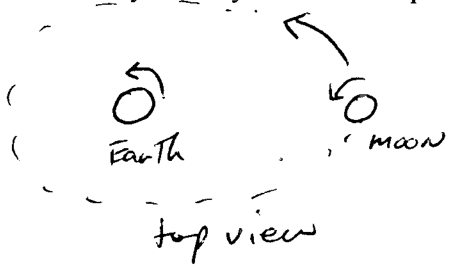
2) (25 points) Rotation of the Earth

In this problem, we look at the angular momentum of the Earth-Moon system. Please consider the Earth and Moon to be uniform spheres (as we discussed it lecture, it's a little more complicated than that, but we ignore that here). Consider the Earth and Moon as an isolated system. Ignore any other celestial bodies, like the Sun, other planets, etc; our motion with respect to them is a topic for the future, not this problem.

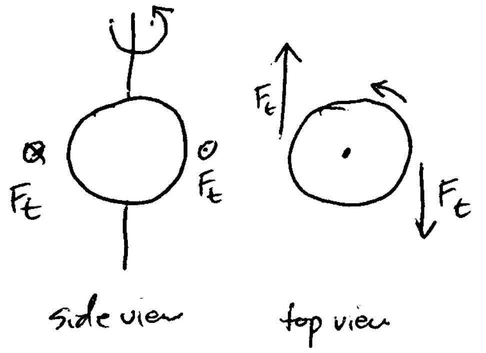
The radius of the Earth is $6x10^6$ meters and its mass is $6x10^{24}$ kg. The Earth turns once in 24 hours, which is $9x10^4$ seconds. The Moon has a radius of $2x10^6$ meters and a mass of $7x10^{22}$ kg. Its orbit about the Earth has a radius of $4x10^8$ meters. The Moon turns on its axis and revolves around the Earth in the same time, 27 days or $2x10^6$ seconds. (If you decide you need any other information, please write a clear definition and assign a distinct variable to it so we can understand your point.)

a) The drawings below are a "side" view of the Earth-Moon system, and a "top view" (from above the northern hemisphere of the Earth). Please sketch on them the direction of the vector representing all the angular momentum of the Earth, the vector representing all of the angular momentum of the Moon, and the vector representing the total angular momentum of the Earth-Moon system. Make sure you label which is which. What are the magnitudes of these three quantities? Please write symbolic expressions first, and then plug in numbers only when you have complete expressions.



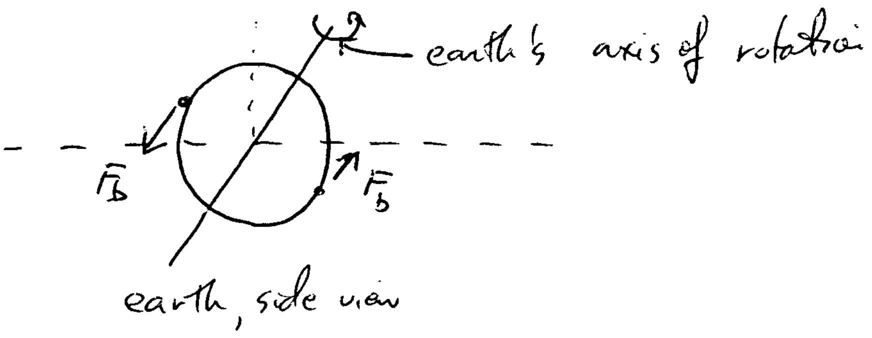


b) Because it causes tides, which we'll discuss later in the course, the Moon exerts some small forces on the Earth in the directions shown. Call each of these F_t, and consider that both act at the surface of the Earth and along the equator (see drawings below). These result in a torque on the Earth. In which direction is it? (Draw a vector on the picture) Write an expression for its magnitude. Does it result in a change in the rotation of the Earth? If so, how does the rotation change? If not, why not?



c) In part (b), we looked at forces exerted on the Earth by the Moon, which resulted in a torque on the Earth. What can you say about torques exerted on the Moon by the Earth? (Not just "what", but if possible "why") Is the total angular momentum of the Earth-Moon system a conserved quantity?

d) A smaller effect occurs because the axis of the Earth is slightly tilted with respect to the orbit of the Moon (see drawing below). For reasons we'll discuss later, this causes the Moon to exert the forces F_b shown below. Again, they act on the surface and at the equator, but these are in a north/south direction. These result in a torque on the Earth. In which direction is it? (Draw a vector on the picture) Write an expression for its magnitude. Does it result in a change in the rotation of the Earth? If so, how does the rotation change? (If need be, draw pictures to explain what you think happens) If not, why not?



3) (3 pts) An object moves in a circle at constant speed. The work done by the centripetal force is zero because:

a) there is no friction

b) the displacement for each revolution is zero

c) the average force for each revolution is zero

d) the magnitude of the acceleration is zero

e) the centripetal force is perpendicular to the velocity

4) (3 pts) The center of mass of a system of particles has a constant velocity if:

a) the center of mass is at the geometric center of the system

b) the forces exerted by the particles on each other sum to zero

c) the external forces acting on particles of the system sum to zero

d) the velocity of the center of mass is initially zero

e) the particles are distributed symmetrically about the center of mass

5) (3 pts) A force acting on a particle is conservative if

a) its work equals the change in kinetic energy of the particle

b) it obeys Newton's second law

c) its work depends on the end points of the motion, not on the path between them

d) it obeys Newton's third law

e) it is not a frictional force

6) (3 pts) The precessional angular velocity of a spinning top increases if:

a) it leans at a larger angle to the vertical

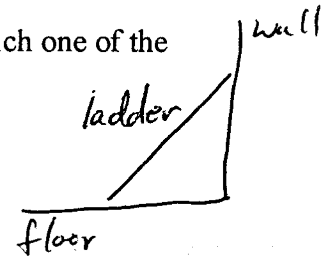
b) it leans at a smaller angle to the vertical

c) its spin angular velocity increases

d) its spin angular velocity decreases

e) none of the above effect the precessional angular velocity

7) (3 pts) A ladder leans against a wall. If the ladder is not to slip, which one of the following must be true?



a) the coefficient of friction between the ladder and the wall must not be zero

b) the coefficient of friction between the ladder and the floor must not be zero

c) both a and b

d) either a or b

e) neither a nor b

8) (3 pts) Suppose a golf ball is hurled at a heavy bowling ball initially at rest and bounces elastically from the bowling ball. After the collision, which ball has the greater momentum?

a) the golf ball

b) the bowling ball

c) both must be the same

d) depends on something we haven't been told

9) (3 pts) Suppose a golf ball is hurled at a heavy bowling ball initially at rest and bounces elastically from the bowling ball. After the collision, which ball has the greater kinetic energy?

a) the golf ball

b) the bowling ball

c) both must be the same

d) depends on something we haven't been told

10) (3 pts) An inelastic collision is one in which

a) momentum is not conserved but kinetic energy is conserved

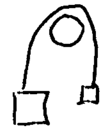
b) total mass is not conserved but momentum is conserved

c) neither kinetic energy nor momentum is conserved

d) momentum is conserved, but kinetic energy is not conserved

e) the total impulse is equal to the change in kinetic energy

11) (3 pts) A massless rope passes over a massless pulley attached to the ceiling. A large mass is tied to one end, and a smaller mass is tied to the other. Starting from rest the large mass moves downward and the smaller mass moves upward with the same acceleration. Which of the following is true for the system consisting of the two masses?



a) the center of mass remains fixed

b) the net external force is zero

c) the velocity of the center of mass is constant

d) the acceleration of the center of mass is g, downward

e) none of the above

12) (3 pts) When a certain rubber band is stretched a distance x, it exerts a restoring force of magnitude $F = Ax$, where A is a constant. The work done by a person stretching this rubber band from $x=0$ to $x=L$ is

a) AL^2

b) $A+2L$

c) $A+2L^2$

d) A/L

e) $1/2\ AL^2$

13) (3 pts) An Oakland A's baseball player catches a ball of mass m which is moving toward him with speed v. While bringing the ball to rest, his hand moves back a distance d. Assuming constant acceleration, the force exerted by his hand on the ball is

a) mv/d

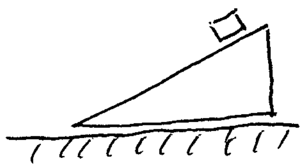
b) mvd

c) mv^2/d

d) $2mv/d$

e) $mv^2/(2d)$

14) (3 pts) A large wedge rests on a horizontal frictionless surface. A block starts from rest and slides down the including surface of the wedge, which is not frictionless. During the motion of the block, the center of mass of the block and wedge



a) does not move

b) moves horizontally with constant speed

c) moves horizontally with increasing speed

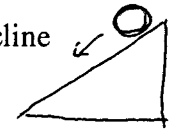
d) moves vertically with increasing speed

e) moves horizontally and vertically

15) (3 pts) If a sphere is pivoted about an axis that is tangent to its surface, its rotational inertia is

a) $1/5\ MR^2$
b) $3/5\ MR^2$
c) MR^2
d) $7/5\ MR^2$
e) $9/5\ MR^2$

16) (3 pts) We may apply conservation of energy to a cylinder rolling down an incline without slipping, thus saying no work is done by friction, because



a) there is no friction present
b) the angular velocity of the center of mass about the point of contact is zero
c) the coefficient of kinetic friction is zero
d) the linear velocity of the point of contact (relative to the surface) is zero
e) the coefficients of static and kinetic friction are equal in this case

17) (3 pts) When a particle collides elastically head-on with another particle, initially at rest, the greatest fraction of the kinetic energy of the incident particle is transferred to the stationary one if:

a) the incident particle is initially travelling very fast
b) the incident particle is travelling very slowly
c) the incident particle is much more massive than the target particle
d) the incident particle is much less massive than the target particle
e) the incident and target particles have the same mass.