Massachusetts Institute of Technology - Physics Department

Physics - 8.01 **Assignment #6** October 22, 1999.

It is strongly recommended *that you read about a subject* ***before*** *it is covered in lectures.*

Lecture Date	Material Covered	Reading
Mon 10/25	**Exam #2**	**Handout of 10/18**
#19 Wed 10/27	Rotating Rigid Bodies - Moment of Inertia	Page 296–309
	Parallel Axis and Perpendicular Axis Theorem	
	Rotational Kinetic Energy - Flywheels	*Handout of 10/27*
	Neutron Stars - Pulsars	***Take Notes***
#20 Fri 10/29	Angular Momentum - Torques	Page 310–317, 327–329
	Conservation of Angular Momentum	Page 336 (Ex. 7), Page 338 (Ex. 9)
	Spinning Neutron Stars - Stellar Collapse	***Take Notes***

Due Monday, Nov 1, before 4 PM in 4-339B.

6.1 *Serious Car Accident* – page 291, problem 13

6.2 *Colliding Bobs* – page 292, problem 23

6.3 *Sliding on Ice*

John and his friend, Nancy, sit motionless on sleds on frictionless ice. John slides a 10 kg block across the ice to Nancy at 3 m/sec relative to his sled (i.e. after the block is released, the relative velocity of the block relative to his sled is 3 m/sec). Nancy catches it and slides it back to John at the same speed of 3 m/sec relative to her own sled. John and his sled (without the 10 kg block) together have a mass of 100 kg, and Nancy and her sled together have a mass of 80 kg.

a) What is the speed of John's sled and what the speed of the block after John releases the block?

b) What is the speed of Nancy's sled immediately after she catches the block?

c) What is the speed of Nancy's sled and what is the speed of the block after she slides the block back to John?

d) What is the speed of John's sled after he catches the block?

e) What is the total kinetic energy of the block and the sled after John releases the block?

f) What is the total kinetic energy of the two sleds and the block just after Nancy catches the block?

g) What is the total kinetic energy of the sleds and the block just after Nancy releases the block?

h) What is the total kinetic energy of the sleds after John catches the block?

i) The kinetic energy is sometimes increasing. Where is that energy coming from?

6.4 *Colliding Pucks* – ***PIVoT***

Two pucks of mass m_1 and m_2, moving on a horizontal frictionless surface, undergo an *elastic* collision. Prior to the collision, their speeds were v_1 and v_2 respectively, as measured in their center-of-mass frame (the frame in which the center of mass is at rest).

a) What are their speeds, as measured in the center-of-mass frame, after the collision?

b) Can you make any statement about their directions of motion after the collision?

c) What was the total kinetic energy before the collision in the center-of-mass reference frame?

d) What was the total kinetic energy after the collision in the center-of-mass reference frame?

6.5 *Surprising Bounce – Lecture Demo*
In lectures we dropped a tennis ball on top of a much heavier basketball from a height of about 3 m. The tennis ball bounced up much higher than 3 m. Calculate how high the tennis ball bounced up by approximating the bounce as the result of two one-dimensional collisions in which first the basketball bounced off the floor and then collided with the falling tennis ball. Thus, in this second collision the two balls had velocities in opposite directions. Assume that the collisions were elastic.

6.6 *Center of Mass Motion and Internal Energy*
A 6 kg object is moving in 1 dimension with a speed of 350 m/sec on a horizontal frictionless surface. It explodes and breaks apart into one fragment of 2 kg and one of 4 kg with velocities along the initial direction of motion of 250 m/sec and 400 m/sec, respectively.

a) What is the total momentum before and after the object explodes? Is momentum conserved?
b) What is the total kinetic energy before and after the object explodes? Is mechanical energy conserved?
c) What is the center-of-mass velocity before and after the object explodes? Does it change?
d) Answer the questions under a) and b), but evaluate all quantities in the center-of-mass frame of reference. Do any of your conclusions change?

6.7 *Oscillating Masses on Frictionless Table –* ***PIVoT***
Two masses, A and B are connected by a spring. The mass of A is m, and the mass of B is $3m$; the mass of the spring is negligible. The spring, with spring constant k, is compressed so that the potential energy stored in the spring is U_0. The system is placed on a horizontal frictionless table. The compressed spring is released at time $t = 0$ at which time the two masses have zero speed.

a) What is the initial total mechanical energy of the system (A, B, and the spring)?
b) How much potential energy is stored in the spring when A and B have kinetic energies K_A and K_B, respectively?
c) At some point in time the speed of A is v_A. What then is the speed of B?
d) If A is moving in the $+x$ direction, in what direction is B then moving?
e) What is the period, T, of the oscillations of the two masses?

6.8 *Proton Collision* – page 294, problem 38

6.9 *Space Shuttle*
A Space Shuttle has to increase its speed by firing its thruster rockets. The exhaust gas speed relative to the Shuttle is about 2.5 km/sec, and the mass of the shuttle is about 10^5 kg. What is the mass of the fuel used in increasing the speed from 8.0 km/sec to 8.5 km/sec ?

6.10 *Saturn V*
The Saturn V rocket was used in the Apollo program. It had an initial mass of 2.85 million kg. The burn rate of the rocket was 13.8×10^3 kg/sec (about 14 tons per sec!), which delivered a thrust of 34 million Newtons. Its final mass was 0.77 million kg (770 tons!). Assume that the entire launch is vertically up. In the discussions in lectures (and in Tipler's derivation) air drag was ignored. This, of course is an over-simplification, as air drag must play an important roll. You too may ignore airdrag. Use $g = 10$ m/sec^2.

a) What was the exhaust speed?
b) How long did the engines burn (this is called the burn time)?
c) What was the acceleration at liftoff?
d) What was the acceleration just before the engines stopped?
e) What was the final speed of the rocket?

6.11 *Kerosene Rocket* – page 271, problem 54