Massachusetts Institute of Technology - Physics Department

Physics - 8.01 | **Assignment #7** | November 1, 1999.

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

Lecture Date	Material Covered	Reading
#21 Mon 11/1	Torques - Oscillating Bodies - Hoops	Page 325 – 334, 394 – 396
#22 Wed 11/3	Kepler's Laws - Elliptical Orbits Satellites - Change of Orbits - Ham Sandwich	Page 218 – 229 *Lecture Supplement of 11/3* *See the Home Page*
#23 Fri 11/5	Doppler Effect - Binary Stars Neutron Stars and Black Holes	Page 446 – 450 ***Take Notes!***
#24 Mon 11/8	Rolling Motion - Gyroscopes ***Very Non-Intuitive!***	Page 335 – 336, 339 – 345 *Lecture Supplement of 11/8* *See the Home Page*

Due Monday, Nov 8, before 4 PM in 4-339B.

This is not an easy assignment; start early!

7.1 *Multiple-Stage Rocket* – page 271, problem 55

7.2 *Slingshot Encounters*
Spacecrafts can gain in mechanical energy as they encounter a planet. This may appear as a violation of the conservation of mechanical energy, but it is not. The gained energy is at the expense of the orbital energy of the planet. The easiest way to see how this works in principle is to treat the problem as a one-dimensional collision. Let the spacecraft have a mass m and just before the encounter a velocity v, the planet a mass M and velocity V. Both velocities are relative to the sun and they are in opposite directions. Thus the angle between v and V is 180°. Assume that the spacecraft rounds the planet and departs in the opposite direction. Thus, after the encounter the velocity of the spacecraft is in the same direction as V.

a) What is the speed of the spacecraft after the encounter in terms of m, M and the speed of the spacecraft before the encounter and the speed of the planet before the encounter?

b) The speed of the spacecraft just before the encounter is 10 km/sec and the speed of the planet 13 km/sec (this is the orbital speed of Jupiter). What then is the speed of the spacecraft just after the encounter?

c) If the spacecraft has a mass of 2000 kg, by how much has its energy increased?

7.3 *Figure Skater* – page 320, problem 23

7.4 *Parallel Axis Theorem* – page 320, problem 26 ***PIVoT***

7.5 *Pulsars* – page 322, problem 41

7.6 *Perpendicular Axis Theorem* – page 322, problem 45 ***PIVoT***

7.7 *Change of Angular Momentum due to a Torque* – page 324, problem 59 ***PIVoT***

7.8 *Spin Up of Disk due to a Torque* – page 348, problem 11 ***PIVoT***

7.9 *A Classic! - Translation and Rotation* ***PIVoT*** — Look under "non-conservation of angular momentum" (you will also see some demonstrations there) and under "conservation of angular momentum". A rod is lying at rest on a perfectly smooth horizontal surface (no friction). We give the rod a short impulse (a hit) perpendicular to the length direction of the rod at P. The mass of the rod is 3 kg, its length is 50 cm, the impulse is 4 kg·m/sec, the distance from the center C of the rod to P is 15 cm.

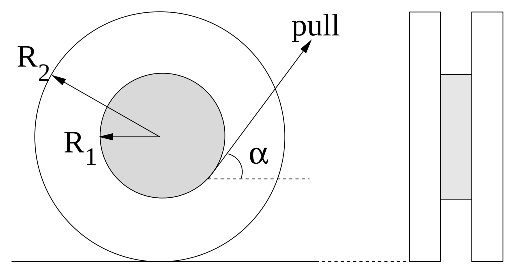
a) What is the translational speed of C after the rod is hit?

b) What is the angular velocity ω of the rod about C?

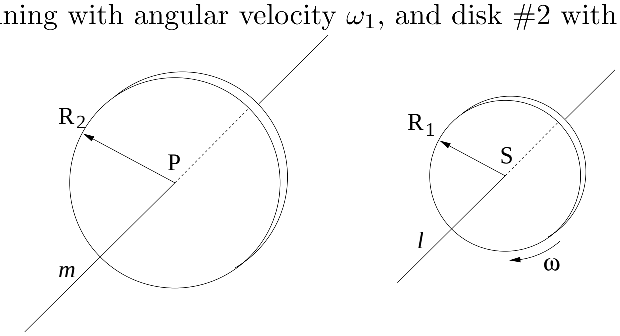
c) What is the position of the rod 8 sec after it was hit; how far did C move, and what is the angle between the direction of the rod and its direction before it was hit?

d) What is the total kinetic energy of the rod after it was hit?

7.10 *The Amazing Yo-Yo!* ***PIVoT***
A yo-yo rests on the floor (the static friction coefficient with the floor is μ). The inner (shaded) portion of the yo-yo has a radius R_1, the two outer disks have radii R_2. A string is wrapped around the inner part. Someone pulls on the string at an angle α (see sketch). The "pull" is very gentle and carefully increased until the yo-yo starts to roll. *Try it at Home; it's Fun!* ***You can watch the demo on PIVoT!*** For what angles of α will the yo-yo roll to the left and for what angles to the right?



7.11 *This is a difficult problem - It too is a Classic!*
A solid disk with radius R_1 is spinning about a horizontal axle l at an angular velocity ω (it rotates freely; friction is ignored). The axle is perpendicular to the disk; it goes through the center S of the disk. The circumference of this disk (#1) is pushed against the circumference of another disk which is in all respects identical to #1 except that its radius is R_2, and it is at rest. It can rotate freely about a horizontal axle, m, through P; m and l are parallel. The friction coefficient between the two touching surfaces (disk circumferences) is μ. We wait until an equilibrium situation is reached. At that time disk #1 is spinning with angular velocity ω_1, and disk #2 with angular velocity ω_2.



a) Is kinetic energy of rotation conserved? Give your reasons.
Now imagine that you are doing this "experiment" and that you hold one axle m in your left hand and axle l in your right hand; you keep them parallel.

b) Do you have to apply a torque while you are pushing the disks against each other?

c) Is the total angular momentum of the two disks conserved?

d) Calculate ω_1 and ω_2 in terms of R_1, R_2, and ω. It is quite remarkable that ω_1 and ω_2 are independent of μ and independent of the time it takes for the equilibrium to be reached; i.e., independent of how hard one pushes the disks against each other.