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Problems set # 7 **Physics 168**

1. A rocket of mass m traveling with speed v_0 along the x axis suddenly shoots out fuel, equal to 1/3 of its mass, parallel to the y axis (perpendicular to the rocket as seen from the ground) with speed $2v_0$. Give the components of the final velocity of the rocket.

2. A laser jet is directed at the Moon, 380,000 km from Earth. The beam diverges at an angle $\theta = 1.4 \times 10^{-5}$. What diameter spot will it make on the Moon?

3. A compact disk rotates from rest to 500 rev/min in 5.5 s. (a) What is the angular acceleration, assuming that it is constant? (b) How many revolutions does the disk make in 5.5 s? (c) How far does a point on the rim 6 cm from the center of the disk travel during the 5.5. s it takes to get 500 rev/min?

4. Figure 1 shows the planet Saturn moving in the negative x direction at its orbital speed (with respect to the Sun) of 9.6 km/s. The mass of Saturn is 5.69×10^{26} kg. A spacecraft with mass 825 kg approaches Saturn. When far from Saturn, it moves in the plus x direction at 10.4 km/s. The gravitational attraction of Saturn (a conservative force) acting on the spacecraft causes it to swing around the planet (orbit shown as dashed line) and head off in the opposite direction. Estimate the final speed of the spacecraft after it is far enough away to be considered free of Saturn's gravitational pull.

5. An object consists of four point particles, each of mass m, connected by rigid massless rods to form a rectangle of edge lengths $2a$ and $2b$, as shown in Fig. 1. The system rotates with angular speed ω about an axis in the plane of the figure through the center. Find the kinetic energy of this object.

6. Find the moment of inertia of the system for rotation about an axis parallel to the first axis but passing through two of the particles. (See Fig. 2.)

7. Estimate the moment of inertia of a thin uniform rod of length L and mass M about an axis perpendicular to the rod and through one end. Execute this estimation by modeling the rod as three point masses, each point mass representing 1/3 of the rod.

8. Find the moment of inertia of a thin uniform rod of length L and mass M about an axis perpendicular to the rod and through one end.

9. A thin uniform rod of mass M and length L on the x axis has one end at the origin. Using the parallel-axis theorem, find the moment of inertia about the y' axis, which is parallel to the y axis, and through the center of the rod.

10. To get a flat, uniform cylindrical satellite spinning at the correct rate, engineers fire four tangential rockets as shown in Fig. 3. If the satellite has a mass of 3600 kg and a radius of 4 m, what is the required steady force of each rocket if the satellite is to reach 32 rpm in 5 min?

11. A helicopter rotor blade can be considered a long thin rod. (a) If each of the three rotor helicopter blades is 3.75 m long and has a mass of 160 kg, calculate the moment of inertia of the three rotor blades about the axis of rotation. (b) How much torque must the rotor apply to bring the blades up to a speed of 5 rev/s in 8 s?

12. Calculate the moment of inertia for H_2O molecule about an axis passing through the center of the oxygen atom (a) perpendicular to the plane of the molecule, and (b) in the plane of the

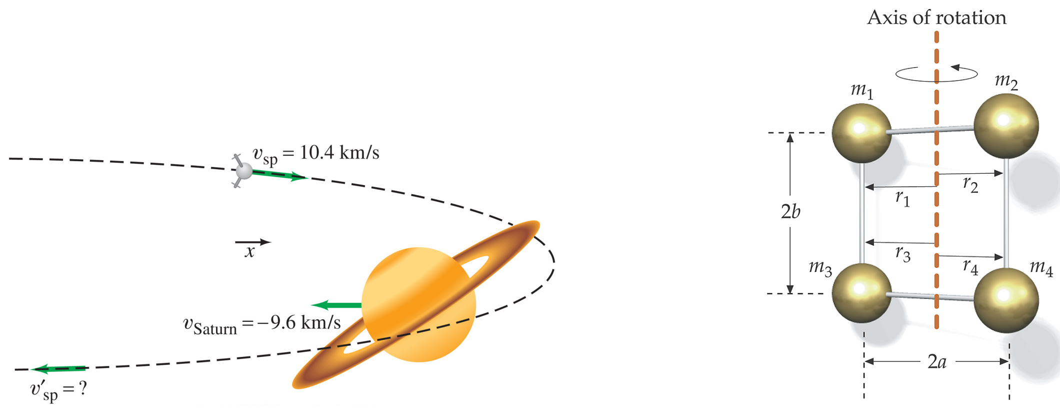

Figure 1: The situations in problems 4 (left) and 5 (right).

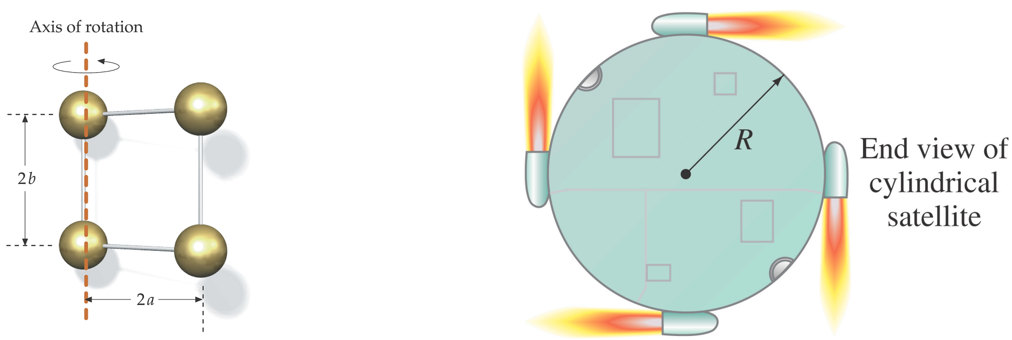

Figure 2: The situations in problems 6 (left) and 10 (right).

molecule, bisecting the H-O-H bonds, see Fig. 3.

13. A 0.25 kg skeet (clay target) is fired at an angle of 30° to the horizon with a speed of 25 m/s, as shown in Fig. 3. When it reaches the maximum height, it is hit from below by a 15-g pellet traveling vertically upward at a speed of 200 m/s. The pellet is embedded in the skeet. (a) How much higher did the skeet go up? (b) How much extra distance, Δx, does the skeet travel because of the collision?

14. The Saturn V rocket used in the Apollo moon-landing program had an initial mass $m_0 = 2.85 \times 10^6$ kg, 73 percent of which was fuel, a burn rate $\alpha = 13.84 \times 10^3$ kg/s, and a thrust $F_{\text{thrust}} = 34 \times 10^6$ N. Find (a) the exhaust speed relative to the rocket, (b) the burn time t_{b}, (c) the acceleration at liftoff, (d) the acceleration at just before burnout t_{b}, and (e) the final speed of the rocket.

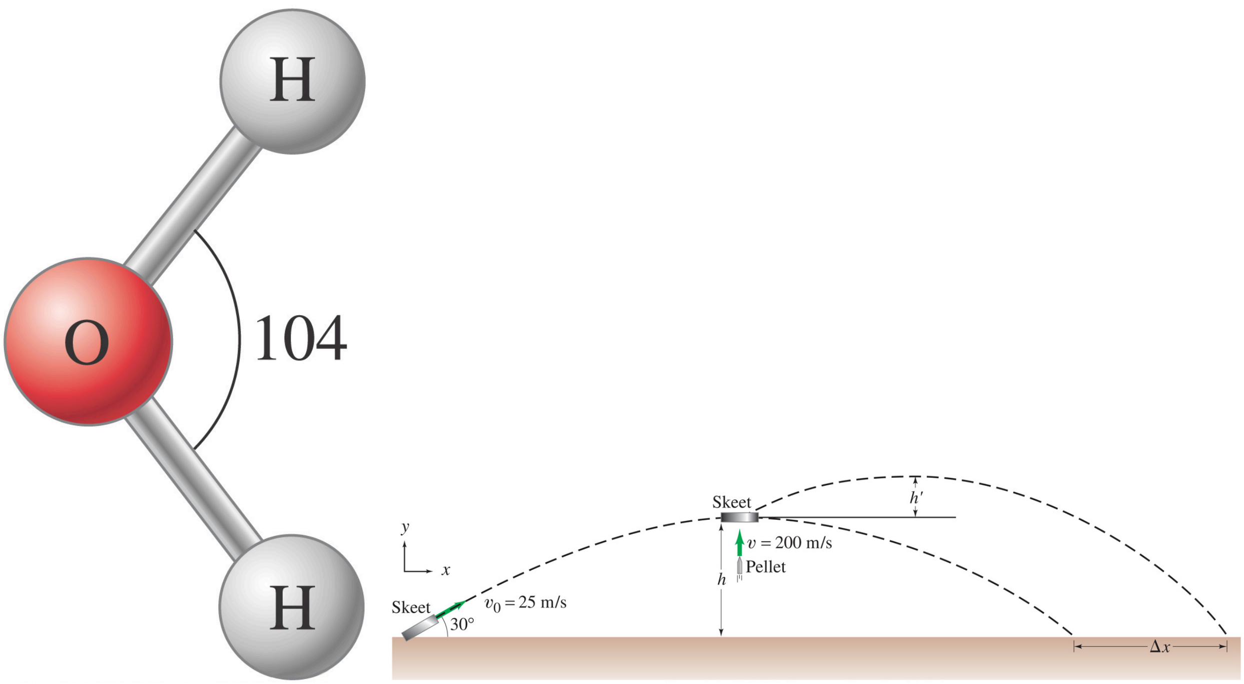

Figure 3: The situations in problems 12 (left) and 13 (right).