University Physics A(1) 2013

Worksheet #7

Name (名字): Student number (学号):

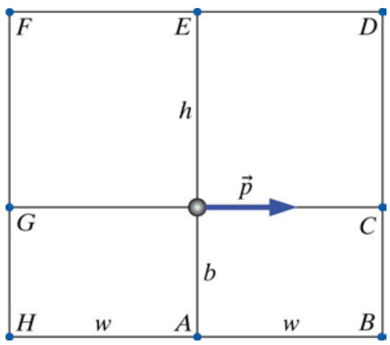
New words: Write the Chinese next to these words as you learn them.

angular momentum	axis
torque	relative to…

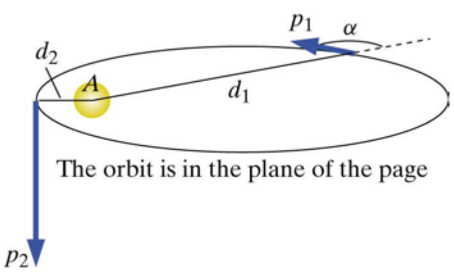
Exercises Answers given at the end. [3 points for attempting them]

- *Translational angular momentum:* $\left|\vec{L}_{\text{trans},A}\right| =$

(1) Determine both the direction and the magnitude of the angular momentum of the particle in the figure below, relative to locations D, E, F, G, and H. (A, B and C are done as examples in the book – see p 420.) The magnitude of the momentum is $|\vec{p}| = 10$ kg m/s; the distances are h = 5 m, b = 3 m and w = 4 m.



(2) A comet orbits the Sun. When it is at location 1 it is a distance d_1 from the Sun, and has momentum of magnitude p_1. Location A is at the center of the Sun. When the comet is at location 2, it is a distance d_2 from the Sun, and has momentum of magnitude p_2.



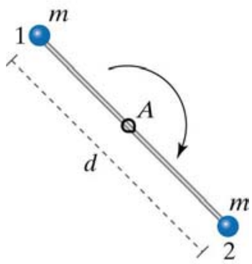
(a) When the comet is at location 1, what are the direction and magnitude of $\vec{L}_A$?

(b) When the comet is at location 2, what are the direction and magnitude of $\vec{L}_A$?

(Later, we will see that that the Angular Momentum Principle tells us that the angular momentum at locations 1 and 2 must be equal.)

- *Rotational angular momentum:* $\vec{L}_{\text{rot}} =$

(3) A barbell (杠铃) spins around a pivot at its center at location A. The barbell consists of two small balls, each with mass m = 0.4 kg, at the ends of a very low-mass rod of length d = 0.6 m. The barbell spins clockwise with angular speed ω_0 = 20 radians/s.



(a) Consider the two balls separately, and calculate $\vec{L}_{\text{trans},1,A}$ and $\vec{L}_{\text{trans},2,A}$ (both direction and magnitude).

(b) Calculate $\vec{L}_{\text{tot},A} = \vec{L}_{\text{trans},1,A} + \vec{L}_{\text{trans},2,A}$ (both direction and magnitude).

(c) Next, consider the two balls together and calculate I for the barbell.

(d) What is the direction of the angular velocity $\vec{\omega}_0$?

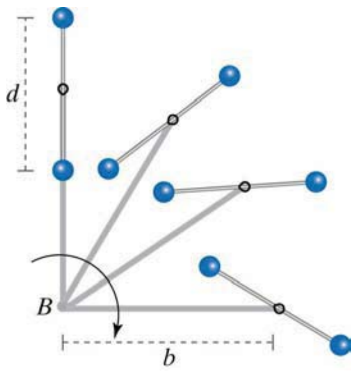
(e) Calculate $\vec{L}_{\text{rot}} = I\vec{\omega}_0$.

(f) How does $\vec{L}_{\text{rot}}$ compare to $\vec{L}_{\text{tot},A}$? [重点: the equation $I\vec{\omega}_0$ is just a convenient way of adding up the translational angular momenta around the center of mass for all the particles in a system.]

(g) Calculate K_{rot}.

- *Total angular momentum*

(4) The barbell in the previous exercise is mounted on the end of a low-mass rigid rod of length b = 0.9 m. The apparatus is started in such a way that it rotates with angular speed ω_1 = 15 rad/s, and in addition, the barbell rotates clockwise about its center with an angular speed ω_2 = 20 rad/s.



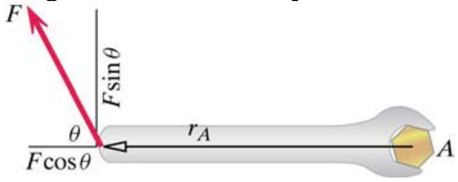
(a) Calculate $\vec{L}_{\text{rot}}$ (both direction and magnitude).

(b) Calculate $\vec{L}_{\text{trans},B}$ (both direction and magnitude).

(c) Calculate $\vec{L}_{\text{tot},B}$ (both direction and magnitude).

- *Torque:* $\vec{\tau}$ =

(5) (a) In the figure below, if r_A = 3 m, F = 4 N, and θ = 30°, what is the magnitude of the torque about location A?



(b) If the force were perpendicular to $\vec{r}_A$ but gave the same torque as in part (a), what would the magnitude of the force be?

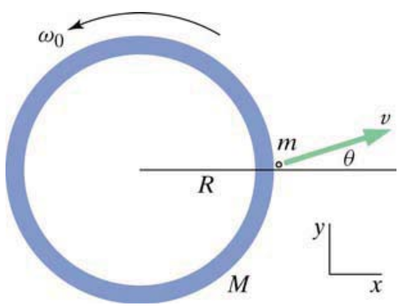
- *Angular Momentum Principle:* $\Delta\vec{L}_A =$

(6) At t = 15 s, a particle has angular momentum $\langle 3, 5, -2\rangle$ kg m^2/s relative to a location A. A constant torque of $\langle 10, -12, 20\rangle$ Nm relative to location A acts on the particle. At t = 15.1 s, what the angular momentum of the particle?

(7) For the (comet + Sun) system in exercise 2, assuming there is no external torque about the Sun, the total angular momentum relative to the Sun must be constant. What is the relationship between the comet's speed when it is closest to the sun (v_{close}, at distance r_{close}) and when it is farthest from the Sun (v_{far}, at distance r_{far})?

Problems Show all working. [7 points in total]

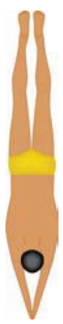
(1) A space station (航天展) has the shape of a hoop (环) of radius R, with mass M. Initially its center of mass is not moving, but it is spinning with angular speed ω_0. Then a small package of mass m is thrown by a spring-loaded gun toward a nearby spacecraft as shown; the package has a speed v just after launch. Calculate the center-of-mass velocity of the space station (v_x and v_y) and its rotational speed ω after the launch. *Be clear about which principles you use to solve the problem.* [3]



(2) A diver dives from a high platform. When he leaves the platform, he tucks tightly and performs three complete revolutions in the air. He then straightens out with his body fully extended before entering the water. He is in the air for a total time of 1.4 seconds.

(a) What is his angular speed ω just as he enters the water? Give a numerical answer, briefly explaining the details of your model. You will need to **estimate** some quantities. [You can find the moments of inertia for different shapes in Chap 9 of the book – p 359.] [3]

(b) Estimate the minimum amount of chemical energy the diver must expend to straighten out his body. [1]



Answers to exercises

(1) D: 50 kg m^2/s out of page; E: 50 kg m^2/s out of page; F: 50 kg m^2/s out of page; G: 0; H: 30 kg m^2/s into page

(2) (a) out of page, $d_1 p_1 \sin\alpha$; out of page, $d_2 p_2$

(3) (a) For both balls: 0.72 kg m^2/s, into page; (b) 1.44 kg m^2/s, into page; (c) I = 0.072 kg m^2; (d) $\vec{\omega}_0$ into page; (e) 1.44 kg m^2/s, into page; (f) They're the same; (g) K_{rot} = 14.4 J

(4) (a) 1.44 kg m^2/s, into page; (b) 9.72 kg m^2/s, into page; (c) 11.16 kg m^2/s, into page

(5) (a) 6 N m; (b) 2 N

(6) $\langle 4, 3.8, 0\rangle$ kg m^2/s

(7) $v_{\text{far}} = (r_{\text{close}}/r_{\text{far}})v_{\text{close}}$