Chapter 9 Questions

1. In figure below suppose that the sled and penguin are initially moving rightward at speed \( v_0 \). (a) As the penguin waddles to the right edge of the sled, is the speed \( v \) of the sled less than, greater than, or equal to \( v_0 \)? (b) If the penguin then waddles back to the left edge, during that motion is the speed \( v \) of the sled less than, greater than, or equal to \( v_0 \)?

(a) **Answer:** As the penguin waddles to the right edge of the sled, the speed of the sled is **less than** \( v_0 \).

The sled with penguin is on frictionless ice and, during motion along the horizontal ice, the weight of both objects does not do any work. Therefore, the sled-penguin system is isolated system and its total linear momentum is conserved. Prior to the penguin’s waddle both objects move to the right with \( v_0 \). While moving to the right along the moving sled, penguin has speed larger than \( v_0 \) relative to ice. To conserve the total linear momentum, the sled has to move slower toward right.

(b) **Answer:** As the penguin waddles back to the left edge of the sled, the speed of the sled is **larger than** \( v_0 \).

The penguin now moves to the left relative to the sled (or at least with the velocity smaller than \( v_0 \) relative to ice), so to conserve the total linear momentum, the sled moves to the right with the larger speed than \( v_0 \).

2. A spaceship that is moving along an \( x \) axis separates into two parts, like the hauler in Fig. 9-12. (a) Which of the graphs in Figure 1 could possibly give the position versus time for the ship and the two parts? (b) Which of the numbered lines pertains to the trailing part? (c) Rank the possible graphs according to the relative speed between the parts, greatest first.

(a) **Answer:** Graphs (a), (d), and (f) could possible give the position versus time for the ship and the two parts.
In the $x-t$ plot, velocity at any point is presented as the \textbf{slope} of the tangent drawn in that point of the curve.

The spaceship is an isolated system, so even after separation (due to the internal forces) the center of mass of the two parts (what’s left of the spaceship and the trailing part) does not change its velocity. Therefore, the initial line can split in two (1 and 3) only if it remains between them.

(b) \textbf{Answer:} The line numbered 2 pertains to the trailing part.

The trailing part separates from the ship by moving, relative to the ship, in the opposite direction (according to Fig. 9-12), so the ship moves faster as the result. So, the line 1 should be above the initial line and the line 2 should be bellow.

(c) \textbf{Answer:} The relative speed between parts: $\text{(d)} > \text{(f)} > \text{(a)}$.

The relative speed between parts is larger for the larger displacement between parts after the ejection of the trailing part. Note: the last plot shows a situation when the trailing part is ejected with such relative speed that, after ejection, it remains at rest relative to Sun, while the ship moves faster as the result.

3. A projectile body moving in the positive direction of an $x$ axis on a frictionless floor runs into an initially stationary target body (as in Fig. 9-19) in a one-dimensional collision. Assume the particles form a closed, isolated system. Nine choices for a graph of the linear momenta of the bodies versus time (before and after the collision) are given in Figure 2. Determine which choices represent physically impossible situations and explain why.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig9-19.png}
\caption{Fig. 9-19}
\end{figure}

\textbf{Answer: (a), (b), (e), (h), and (i).}

The projectile-target system is a closed, isolated system. Therefore, total linear momentum of the system is conserved. Prior to the one-dimensional collision the projectile moves in the positive $x$ direction and the target is at rest. So, the total linear momentum should be also in the positive $x$ direction and equal to the linear momentum of the initially moving particle.

After the collision: in (b) the total linear momentum is larger than the initial; in (e) the total linear momentum is zero; in (h) the total linear momentum is positive but smaller than initial; and in (i) the total linear momentum is in the opposite direction (and larger) than initial.

In the situation of one object at rest prior to the collision, that object can only move in the direction equal to the initial direction of the other. That condition excludes the situation (a) as well.
Chapter 10 Questions

1. In the overhead view below, five forces of the same magnitude act on a square that can rotate about point P, at midlength along one of the edges. Rank the forces according to the magnitude of the torque they create about point P, greatest first.

   Answer: \((5) > (4) > (2) > (1) > (3) = 0\).

   The torque, \(\vec{\tau}\), is a vector product between the force, \(\vec{F}\), and the position vector \(\vec{r}\), (vector from the point \(P\) to the point where the force \(\vec{F}\) acts). The magnitude of the torque is: 
   \[ |\vec{F}| |\vec{r}| \sin \phi \text{, where } \phi \text{ is the smaller angle between the two vectors.} \]

   In this case, \(|\vec{F}|\) is the same, so we should compare \(|\vec{r}| \sin \theta\), called moment arm of force, for each force. The moment arm is the perpendicular distance between the point \(P\) and the line of action of the force.

2. Figure gives the angular velocity \(\omega\) versus time \(t\) for a merry-go-around being turned by a varying applied force. The magnitudes of the curve’s slopes in time intervals 1, 3, 4, and 6 are equal. (a) During which of the time intervals is energy transferred from the merry-go-round by the applied force? (b) Rank the time intervals according to the work done on the merry-go-round by the applied force during the interval, most positive work first, most negative work last. (c) Rank the intervals according to the rate at which the applied force transfers energy, greatest rate of transfer to the merry-go-round first, greatest rate of transfer from it last.
(a) The energy is transferred from the merry-go-round by the applied force while the merry-go-round slows down (its angular speed decreases). This happens during periods 3 and 6.

(b) According to the work-kinetic energy theorem,
\[ W = \Delta K = \frac{1}{2}I(\omega_f^2 - \omega_i^2), \]
work done by a force is positive when kinetic energy increases and is negative when kinetic energy decreases. During no change in angular speed no work is done. Therefore, the time intervals in order of the work done are:
\[ (1) > (4) > (2) = (5) = 0 > (6) > (3). \]

(c) The power (the rate of transfer of energy) is ratio between work done and time the work was accomplished. Time intervals 1 and 3 are the same and twice the time intervals 4 and 6, that are the same: \( t_1 = t_3 = 2t_4 = 2t_6 \). The work done during period (1) is four times larger than the work done during period (4), while power is only twice the power during period 4, but is still larger. Similar holds for intervals 3 and 6 for the magnitudes of the work done.

Therefore, the time intervals in the order of the rate at which the applied force transfers energy (power) are:
\[ (1) > (4) > (2) = (5) = 0 > (6) > (3). \]

3. Figure 10-28 shows three flat disks (of the same radius) that can rotate about their centers like merry-g-rounds. Each disk consists of the same two materials, one denser than the other (density is mass per unit volume). In disks 1 and 3, the denser material forms the outer half of the disk area. In disk 2, it forms the inner half of the disk area. Forces with identical magnitudes are applied tangentially to the disk, either at the outer edge or at the interface of the two materials, as shown. Rank the disks according to (a) the torque about the disk center, (b) the rotational inertia about the disk center, and (c) the angular acceleration of the disk, greatest first.

We have three flat disks, with the same size (same inner circle radius \( R_c \) and the same outer shell radius \( R_s \)), the same two materials with densities \( \rho_1 \) and \( \rho_2 \) with \( \rho_1 > \rho_2 \), with the area of the inner circle equal to the area of the outer shell, \( A_c = A_s \), and the same forces. Also, the total mass of each disk is the same.

(a) The torque about the disk center is \( R_s F \) for the disks 1 and 2, and it is \( R_c F \) for the disk 3. The inner circle is smaller than the outer, so \( \tau_{com,1} = \tau_{com,2} > \tau_{com,3} \).

(b) The rotational inertia of disks 1 and 3 are the same by inspection. The rotational inertia of disk 2 is smaller because it has more mass (the same area but denser material) closer to the center of mass than either disk 1 or 2. Therefore, \( I_1 = I_3 > I_2 \).

(c) The angular acceleration is \( \alpha = \frac{\tau}{I} \) so the larger the rotational inertia the smaller the angular acceleration for the same torque, so disk 2 has larger angular acceleration than disk 1. Also, the larger the torque the larger the angular acceleration if the rotational inertia does not change, so disk 1 has larger angular acceleration than disk 3. Therefore, \( \alpha_2 > \alpha_1 > \alpha_3 \).