CHAPTER 5 Review

REFLECTING ON CHAPTER 5

- Inertia is the natural tendency of an object to remain at rest or in uniform motion.
- The amount of inertia depends on the amount of mass of an object.
- **Newton's 1st law:** An object will stay at rest or in straight-line motion at a constant speed unless acted on by an external force.
- In an inertial frame of reference, Newton's laws of motion describe motion correctly. Inertial frames of reference might be stationary or moving at constant velocity.
- In non-inertial frames of reference, Newton's laws of motion do not accurately describe motion. Accelerating frames of reference are non-inertial.
- Fictitious forces are needed to explain motion in non-inertial frames of reference. If the same motion is observed from an inertial frame of reference, the motion can be explained without the use of fictitious forces.
- **Newton's 2nd law:** An object will accelerate in the direction of the unbalanced net force. The magnitude of the acceleration will be proportional to the magnitude of the force and inversely proportional to the mass, $\vec{a} = \frac{\vec{F}}{m}$.
- **Newton's 3rd law:** For every action force on object B, there is an equal in magnitude but opposite in direction reaction force acting back on object A. Thus, forces always act in equal and opposite pairs.
- Free fall is vertical motion that is affected by gravitational forces only. In free fall, all objects accelerate at the same rate.
- Terminal velocity is the maximum downward speed reached by a falling object when the force of air friction becomes equal to the force of gravity.
- Air resistance depends on the surface area, shape, and speed of an object relative to the air around it.
- Newton expressed his second law in terms of momentum: $\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$.
- Rearrangement of Newton's form of the second law yields the quantities of impulse, $\vec{F}\Delta t$, and a change in momentum, $\Delta\vec{p}$, and shows that impulse is equal to the change in momentum: $\vec{F}\Delta t = \Delta\vec{p}$. This expression is called the "impulse-momentum theorem."
- Momentum is mass times velocity $\vec{p} = m\vec{v}$.
- The concept of impulse plays a significant role in the design of safety systems. By extending the time, Δt, of a collision, you can reduce the amount of force, $\vec{F}$, exerted.

Knowledge/Understanding

1. Describe three examples of inertia.
2. The force, $\vec{F}$, in Newton's second law refers to what force or forces? Explain how you determine what force to use in any given problem.
3. Explain the meaning of the phrase, "forces always act in pairs." Give an example of a situation in which it is important to know the relationship between a "pair of forces."
4. Under what circumstances would you choose a coordinate system in which the x-axis is not horizontal? Explain why you would choose such a coordinate system.
5. Describe a situation in which your apparent weight is not the same as your actual weight.
6. Distinguish between, and provide examples of, inertial and non-inertial frames of reference.
7. Write Newton's second law in terms of momentum. Show how this expression of Newton's law leads to the definition of impulse and to the impulse-momentum theorem.
8. Give an example of a situation in which it is easier to measure data that you can use to calculate a change in momentum than it is to determine forces and time intervals.

9. In many professional auto races, stacks of old tires are placed in front of walls that are close to turns in the racetrack. Explain in detail, using the concept of impulse, why the tires are stacked there.

Inquiry

10. Sketch a graph that shows the velocity of a sky diver through three phases:
    (a) from the time she jumps from the plane to the time when she opens her parachute
    (b) from the time when she opens her parachute to the time when she reaches terminal velocity
    (c) from the time when she reaches terminal velocity, with her parachute fully deployed, until the time when she lands
    Use the graph to make conclusions about the forces acting on the sky diver during each of the three phases of her fall.
11. A sky diver uses a GPS system to measure his velocity every second during a free fall. The recorded velocities at the end of each of the first 5 seconds are 9.5 m/s, 18 m/s, 25 m/s, 30 m/s, and 32 m/s. Plot a velocity-time graph of this free fall, assuming his velocity is 0 m/s at time 0 s. Is the graph linear? What does the shape of the graph imply about the sky diver's acceleration and the forces acting on him during these 5 seconds?
12. In Investigation 5-A on page 160, you varied the force on a dynamics cart and observed the change in the cart's acceleration. Design an experiment to test what happens to the acceleration of the cart when its mass is varied, instead of the force.
13. The International Tennis Federation (ITF) approaches you, a physics student, complaining that too many games in tournaments are being won on the strength of either player's serve. They ask you to examine ways to slow down the serve and thus make the game more interesting to watch. Devise a series of experiments to test the ball, the type of racquet used, and the surface of the courts, from which you could make recommendations to the ITF about how to improve the game of tennis.
14. Design a small wooden cart, with several raw eggs as passengers. Incorporate elements into your design to ensure that the passengers suffer no injury if the cart was involved in a collision while travelling at 5.0 m/s. If possible, test your design.

Communication

15. In this chapter, the importance of choosing a frame of reference was emphasized. It was also stated that there is no "right or wrong" way to choose a frame of reference. However, the choice of a reference frame can affect the ease or difficulty in problem solving. Explain how all of these statements can all be true. Explain why certain reference frames can make problem solving very difficult.
16. A large crate sits on the floor of an elevator. The force of static friction keeps the crate from moving. However, the magnitude of this force changes when the elevator **(a)** is stationary, **(b)** accelerates downward and **(c)** accelerates upward. Explain how the three forces should be ranked from weakest to strongest.
17. Two blocks, of mass M and mass m, are in contact on a horizontal frictionless table (with the block of mass M on the left and the block of mass m on the right). A force F_1 is applied to the block of mass M and the two blocks accelerate together to the right.
    (a) Draw a free-body diagram for each block.
    (b) Suppose the larger block M exerts a force F_2 on the smaller mass m. By Newton's third law, the smaller block m exerts a force F_2 on the larger block M. Argue whether $F_1 = F_2$ or not. Justify your reasoning.
    (c) Derive an expression for the acceleration of the system.
    (d) Derive an expression for the magnitude of the force F_2 that the larger block exerts on the smaller block.

(e) Choose different values of M and m (e.g. $M = 2m$, $M = 5m$, including the case $M = m$) and compare the magnitudes of F_1 and F_2.

(f) Comment on the above results.

18. A car and a bicycle are travelling with the same velocity. Which vehicle has greater momentum? Explain your reasoning.

19. Write the units for impulse and for momentum. Show that these combinations of units are equivalent and explain your reasoning in detail.

Making Connections

20. List all the sports you can think of that involve an object being propelled at high velocity. Choose one of these sports and describe how the sport has been changed, because of technological advances in the equipment or safety concerns in the use of the equipment.

21. Propose a course of action to a government committee looking into building a high-speed rail link between Halifax, Quebec City, and Montreal. The proposal should consider economic, environmental, political, and safety issues.

22. Many automobiles are now equipped with air bags that are designed to prevent injuries to passengers if the vehicle is involved in a collision. Research the properties of air bags. In terms of impulse, how do they work? How quickly do they inflate? Do they remain inflated? What force do they exert on the driver or passenger? What are the safety concerns of using air bags?

Problems for Understanding

23. As it moves through the water a 400 kg boat experiences a resistance force of 2 500 N from the air and 3 200 N force of resistance from the water. If the motor provides a forward force of 6 000 N:

(a) Determine the net force.

(b) Calculate the acceleration of the boat.

24. A toboggan with a mass of 15 kg is being pulled with an applied force of 45 N at an angle of 40° to the horizontal. What is the acceleration if the force of friction opposing the motion is 28 N?

25. A grocery cart is being pushed with a force of 450 N at an angle of 30.0° to the horizontal. If the mass of the cart and the groceries is 42 kg,

(a) Calculate the force of friction if the coefficient of friction is 0.60.

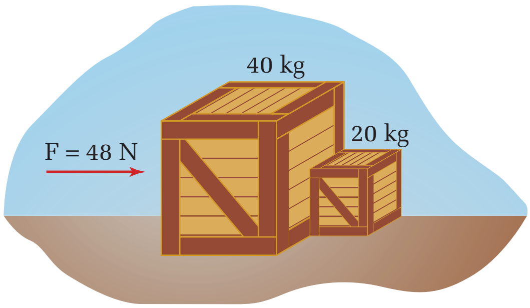
(b) Determine the acceleration of the cart.

26. Calculate the net force if the following three forces are all being applied at the same time: 40 N[S], 60 N[N], and 30 N[N35°E].

27. Two boxes are side by side on a frictionless surface. A horizontal force is applied to move both boxes.

(a) Calculate the acceleration of both boxes.

(b) Determine the force that the 4.0×10^1 kg box applies to the 2.0×10^1 kg box.



28. A physics teacher is in an elevator moving upward at a velocity of 3.5 m/s when he drops his watch. What are the initial velocity and acceleration of the watch in a frame that is attached to **(a)** the elevator and **(b)** the building?

29. **(a)** What is the acceleration of a 68.0 kg crate that is pushed across the floor by a 425 N force, if the coefficient of kinetic friction between the box and floor is 0.500?

(b) What force would be required to push the crate across the floor with constant velocity?

30. If a 0.24 kg ball is accelerated at 5.0 m/s^2, what is the magnitude of the force acting on it?

31. A 10.0 kg brick is pulled from rest along a horizontal bench by a constant force of 4.0 N. It is observed to move a distance of 2.0 m in 8.0 s.
   (a) What is the acceleration of the brick?
   (b) What is the ratio of the applied force to the mass?
   (c) Explain why your two answers above do not agree. Use numerical calculations to support your explanation.
32. A 2200 kg car is travelling at 45 km/h when its brakes are applied and it skids to a stop. If the coefficient of friction between the road and the tires is 0.70, how far does the car go before stopping?
33. A 55.0 kg woman jumps to the floor from a height of 1.5 m.
   (a) What is her velocity at the instant before her feet touch the floor?
   (b) If her body comes to rest during a time interval of 8.00×10^{-3} s, what is the force of the floor on her feet?
34. The maximum acceleration of a truck is $2.6\ m/s^2$. If the truck tows another truck with a mass the same as its own, what is its maximum acceleration?
35. A force F produces an acceleration a when applied to a certain body. If the mass of the body is doubled and the force is increased five-fold, what will be the effect on the following?
   (a) the acceleration of the body
   (b) the distance travelled by the body in a given time
36. A 45.0 kg box is pulled with a force of 205 N by a rope held at an angle of 46.5° to the horizontal. The velocity of the box increases from 1.00 m/s to 1.50 m/s in 2.50 s. Calculate
   (a) the net force acting horizontally on the box.
   (b) the frictional force acting on the box.
   (c) the horizontal component of the applied force.
   (d) the coefficient of kinetic friction between the box and the floor.
37. Determine the momentum of a 5.0 kg bowling ball rolling with a velocity of 3.5 m/s[N] toward a set of bowling pins.
38. What is the mass of a car that is travelling with a velocity of 28 m/s[W] and a momentum of 4.2×10^4 kg · m/s[W]?
39. The momentum of a 55.0 kg in-line skater is 66.0 kg m/s[S]. What is his velocity?
40. How fast would a 5.0×10^{-3} kg golf ball have to travel to have the same momentum as a 5.0 kg bowling ball that is rolling at 6.0 m/s[forward]?
41. Calculate the impulse for the following interactions.
   (a) A person knocks at the door with an average force of 9.1 N[E] over a time interval of 2.5×10^{-3} s.
   (b) A wooden mallet strikes a large iron gong with an average force of 4.2 N[S] over a time interval of 8.6×10^{-3} s.
42. A volleyball player spikes the ball with an impulse of 8.8 kg · m/s over a duration of 2.3×10^{-3} s. What was the average applied force?
43. If a tennis racquet exerts an average force of 55 N and an impulse of 2.0 N · s on a tennis ball, what is the duration of the contact?
44. (a) What is the impulse of a 0.300 kg hockey puck slapshot that strikes the goal post at a velocity of 44 m/s[N] and rebounds straight back with a velocity of 9.2 m/s[S]?
   (b) If the average force of the interaction was -2.5×10^3 N, what was the duration of the interaction?
45. A 2.5 kg curling stone is moving down the ice at 3.5 m/s[W]. What force would be needed to stop the stone in a time of 3.5×10^{-4} s?
46. At an automobile test facility, a car with a 75.0 kg crash-test dummy is travelling 28 m/s[forward] when it hits a wall. Calculate the force that the seat belt exerts on the dummy on impact. Assume that the car and dummy travel about 1.0 m as the car comes to rest and that the acceleration is constant during the crash.