CHAPTER 4
NEWTON'S LAWS OF MOTION

Discussion Questions

Q4.1 No. For an object to be in equilibrium the net force on it must be zero. If there is one and only one non-zero force on the object, the net force isn't zero.

Q4.2 The ball is not in equilibrium. The only force on the ball is gravity. The net force is not zero. The ball has acceleration g downward. The ball has zero velocity at this instant but the velocity will not stay zero.

Q4.3 If the balloon is at rest its acceleration is zero and the net force on it is zero, so it is in equilibrium. The forces on it are the downward force of gravity and the upward buoyant force exerted by the air. These forces must be equal in magnitude, so they add to give zero net force.

Q4.4 The plane has no acceleration. You have the same velocity as the plane.

Q4.5 Let the force applied to each end have magnitude F. For any segment of the rope the force exerted on one end of the segment by the rest of the rope is F; this is what we mean by the tension in the rope.

Q4.6 Before you let go the velocity of the brick is tangent to the circular path. After you let go the only force on the brick is gravity and the brick has downward acceleration g. It has an initial horizontal velocity and travels in projectile motion with a parabolic path.

Q4.7 Newton's 1st law says an object moves with constant velocity unless it is acted on by a nonzero net force. When the car stops suddenly the passengers tend to continue to move with constant velocity, until forces provide an acceleration that stops them. When the car turns, the passengers tend to continue moving in a straight line as the car turns under them.

Q4.8 It is the absence of sufficient force directed opposite to the initial velocity that produces the effect. The passengers continue to move with constant speed until stopped by a force directed backwards. There is no forward force on the passengers.

Q4.9 One possibility is that the bus is accelerating forward so is speeding up, while the ball, with little horizontal force on it continues to move with the initial speed of the bus. Another possibility is that a net force was applied to the ball, for example by someone giving it a push. In the second case the ball was accelerated by the push but after the push is removed it rolls at constant speed relative to the bus. In the first case, so long as the bus is accelerating the ball gains speed relative to the bus. Also, in the first case all objects in the bus would be affected; the passengers would feel an increased horizontal force on them by the seat on which they are sitting as they are accelerated.

Q4.10 $m = F / a$. a has units of length/(time)^2 so m would have units of force$\cdot$(time)^2/length. In the SI system the units would be $\mathrm{N \cdot s^2/m}$.

Q4.11 An accelerating reference frame is an non-inertial frame. The surface of the earth is accelerating. It has $a_{\mathrm{rad}} = v^2 / R$ due to the rotation of the earth about its axis and $a_{\mathrm{rad}} = v^2 / R$ due to the revolution of the earth about the sun. These accelerations are small, but they prevent the frame of the earth from being precisely an inertial reference frame.

Q4.12 No, in all the cases the van is accelerating and is therefore an non-inertial frame.

Q4.13 This quantity is not a force. It represents the effect on the object of the net force on the object.

Q4.14 The elevator moves at constant speed so is an inertial reference frame. The value $g = 9.8$ m/s^2 is obtained, the same as when the elevator is at rest.

Q4.15 No, in this case the bus has a radial acceleration $a_{\text{rad}} = v^2 / R$. The bus turns while the ball travels in a straight line after it is thrown.

Q4.16 The quantity $g = 9.8\ \text{m/s}^2$ is the acceleration produced by the gravity force when it is the only force on an object. It is not a force, it is the acceleration that results from a force. The units m/s^2 are the units for acceleration, not for force.

Q4.17 The hurt comes from the force the rock exerts on your foot. If your foot is moving at high speed and the rock doesn't move, your foot is stopped over a short distance and its acceleration is large. The large acceleration is produced by a large force between your foot and the rock. But even if the force exerted by the pebble is less, it can be exerted over a smaller area and thus do more damage.

Q4.18 A large force is exerted when the acceleration is large. If the object's speed goes from v_0 to zero over a short distance or during a short time then the acceleration of the object is large.

Q4.19 You have the same speed just before impact in either case. But the distance over which you stop is much smaller for the concrete so your acceleration and the force exerted on you is much larger in that case.

Q4.20 The crumpling increases the stopping distance after impact and decreases the acceleration and therefore the force on the car and passengers. The sides and top don't crumple because they are close to the passengers, who could be crushed.

Q4.21 For a steady pull the acceleration is small and the tension in the string is only slightly greater than the weight of the object. If you jerk the string a large acceleration of the object is produced, until the string breaks. Therefore, in this case the tension in the string is much larger than the weight of the object.

Q4.22 When the crate is either at rest or moving at constant speed its acceleration is zero and the tension in the rope equals the weight of the crate. If the crate is traveling upward and speeding up, its acceleration is upward and the net force is upward; the tension in the rope is greater than the weight of the crate. If the crate is traveling upward and slowing down, its acceleration is downward and the tension is less than the weight.

Q4.23 The gravity force is proportional to the mass, so the gravity force on the 20-kg stone is twice the gravity force on the 10-kg stone. The force is related to the acceleration by $\sum \vec{\boldsymbol{F}} = m\vec{\boldsymbol{a}}$, so $\vec{\boldsymbol{a}} = \sum \vec{\boldsymbol{F}} / m$ and the 20-kg stone requires twice the net force to produce the same acceleration.

Q4.24 A kilogram is a unit of mass and a pound is a unit of force. The correct statement is that at a point where $g = 9.8\ \text{m/s}^2$, a 1.0-kg object has a weight (gravity force) of 2.2 lb.

Q4.25 The motion of an object depends on the forces on that object. The force of the horse on the wagon and the force of the wagon on the horse are a third-law pair and act on different objects.

Q4.26 False. Newton's third law requires that *F* and *P* always have equal magnitudes, independent of the other forces on you and the object and independent of any motion you or the object have.

Q4.27 By Newton's 3rd law, $\vec{F}_{\text{T on C}} = -\vec{F}_{\text{C on T}}$; the two forces are equal in magnitude and opposite in direction. This is true no matter how fast each vehicle is moving before the collision.

Q4.28 In both cases, in the absence of air resistance, the only horizontal force is the force that the highway surface applies to the wheels. The highway pushes on the wheels because the wheels push on the highway.

Q4.29 By Newton's 3rd law, the force the car exerts on the van is equal in magnitude and opposite in direction to the force the van exerts on the car. If the vehicles have the same acceleration, the one with the larger mass (the van) has the larger net force on it. In the absence of air resistance the net force on the van is the force exerted by the car. The net force on the car is the force the ground exerts on the car minus the force the van exerts on the car. The force of the ground on the car must be larger than the force of the car on the van.

Q4.30 The free-body force diagram for each person is given in Fig. DQ4.30. The magnitude of the force that *B* exerts on *A* equals the magnitude of the force that *A* exerts on *B*. $F_{\text{g on }A}$ is the magnitude of the force that the ground exerts on *A* and $F_{\text{g on }B}$ is the magnitude of the force that the ground exerts on *B*. The person who wins is the one for whom the ground exerts the larger force. The force of the ground on the person equals in magnitude the force that the person exerts on the ground. So, the winner is the one who exerts the greater horizontal force on the ground.

Figure DQ4.30

Q4.31 Both boxes have the same acceleration a. Treating both objects together as a single object, a force of 100 N gives acceleration a to mass $m_A + m_B$. The force that *A* exerts on *B* gives a smaller mass (m_B) the same acceleration, so this force must be less than 100 N. We can actually calculate this force. Treating both boxes together as a single object, $a = \dfrac{100\text{ N}}{(150\text{ N} + 50\text{ N})/g} = g/2 = 4.9\text{ m/s}^2$.

For box *B*, $F_A = m_B a = \left(\dfrac{50\text{ N}}{g}\right)\left(\dfrac{g}{2}\right) = 25\text{ N}$. By Newton's third law, box *B* pushed to the left on box *A* with force 25 N, so the net force on box *A* is $100\text{ N} - 25\text{ N} = 75\text{ N}$. For box *A*, $ma = (150\text{ N}/g)(g/2) = 75\text{ N}$ so Newton's second law is satisfied.

Q4.32 The first statement is correct. The airplane has constant velocity and the net force on it is zero. The second statement is incorrect. When the airplane is either climbing or descending at a steady rate, its velocity is constant, its acceleration is zero, and the net force on it is still zero. In all these situations the net force equals the weight.

Q4.33 This works because of Newton's 1st law. You place the water into motion along with your hands. You suddenly stop or change the direction of motion of your hands and the water continues to move with constant velocity and leaves your hands.

Q4.34 By Newton's 1st law the blood in your head doesn't have sufficient upward force on it to accelerate upward as rapidly as your head. Blood doesn't stay in your head and this causes the sensation.

Q4.35 The person's lower body receives a large forward acceleration due to the force from the car seat in which the person is sitting. The person's head stays at rest until the force from the neck accelerates it to follow the rest of the body. The head lagging behind produces the whiplash.

Q4.36 It is sloppy physics language to say the passenger is "thrown through the windshield." The windshield stops suddenly due to large forces on the car and the passenger continues to move forward.

Q4.37 By Newton's 3rd law the force the large car exerts on the small car equals in magnitude the force the small car exerts on the large car. Equal forces produce unequal accelerations because the masses are different. The small car experiences the greater acceleration. The passengers in the smaller car experience greater accelerations and have larger forces on them.

Q4.38 (i) It is not possible to determine if the rocket is moving at constant velocity. (ii) Perform experiments and see if Newton's 2nd law is obeyed in the frame of the rocket. If the rocket is accelerating Newton's 2nd law won't be obeyed.