The Fundamentals of

PHYSICS

Volume I

Force and Motion

Checkpoint Answers

Robert A. Cohen
Physics Department
East Stroudsburg University

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1. The Natural State of Things

Check Point 1.1: No. Prior to touching, they aren't interacting.

Check Point 1.2: No. A force only exists when the two objects interact and, prior to touching, they aren't interacting.

Check Point 1.3: No, as "slowing down" would be a change in its motion.

Check Point 1.4: No. There is a only a force due to the interaction while the pitcher is touching the ball.

Check Point 1.5: The object is speeding up. There is a westward force on the object. Since the motion is also westward, the object speeds up.

Check Point 1.6: (a) and (c)

Check Point 1.7: No. An object's inertia is associated with the object itself, not its interaction with another object.

Check Point 1.8: Because at slow speeds the force exerted by the air would be the same all around the object, providing just as much force in the direction of motion as opposite to it.

Check Point 1.9: When the car is moving slowly, since its motion isn't changing. The drag on the fast-moving car is responsible for it slowing down.

2. Multiple Forces

Check Point 2.1: Closer to one newton (probably less). It isn't hard to slide a small coin.

Check Point 2.2: N (capital, not lower-case)

Check Point 2.3: (a) 300 N, (b) Eastward

Check Point 2.4: The forces don't balance, with the westward force being "stronger" than the eastward force. That means the net force is directed westward, with a magnitude equal to 8 N (the difference between 12 N and 20 N).

Check Point 2.5: Yes, it is possible, as long as the two upward forces together equal the magnitude of the forces acting downward.

Check Point 2.6: 50 N. Forces have to be balanced in order to maintain the same speed and direction, so our applied force has to be equal in magnitude to the friction force.

Check Point 2.7: The object speeds up. There is a force imbalance because the westward force is greater than the eastward force. That produces a net force that is westward. Since the motion is also westward, the object speeds up.

Check Point 2.8: (a) The net force needs to be downward, since the object slowed down when it was going up (opposite the net force). (b) The net force needs to be downward, since the object is changing directions from up to down. (c) The net force needs to be downward, since the object is speeding up when it was going down (same direction as net force).

Check Point 2.9: (a) The net force must be upward, opposite my motion. (b) The net force must be zero, since I remain at rest.

Check Point 2.10: (a) No, if you are no longer touching the ball then there is no force on the ball due to you. (b) No, because 3 mph is slow enough that drag can be ignored. (c) The ball's speed will not change, since there are no forces propelling or opposing the motion.

3. Force and Motion Equation

Check Point 3.1: (a) 2000 N northward. (b) 2000 N.

Check Point 3.2: The answer will vary from person to person. A mass of 100 lb is equivalent to 45 kg, while a mass of 150 lb is equivalent to 68 kg, and a mass of 200 lb is equivalent to 91 kg.

Check Point 3.3: Because it involves less zeros. If we were to use the force and motion equation, we'd have to use kilograms (0.005 kg).

Check Point 3.4: 1 hour

$$\Delta\vec{v} = \frac{\vec{F}_{\text{net}}\Delta t}{m} \tag{3.1}$$

Check Point 3.5: (b) and (c)

Check Point 3.6: The change in motion would be less.

Check Point 3.7: Object B. The law of force and motion says that the longer the force is applied, the greater the object's change in velocity.

Check Point 3.8: Even the force is the same and exerted for the same amount of time, the Ping-pong ball would experience a greater change in motion because its mass is smaller.

Check Point 3.9: (a) 20 mph northward. (b) 20 mph.

Check Point 3.10: (a) 20 m/s westward, (b) The change in velocity would be 15 m/s westward, since it starts with a westward velocity and thus undergoes a smaller change.

Check Point 3.11: (b)

4. Using the Force and Motion Equation

Check Point 4.1: No. The result is in meters per second only if you use SI units throughout, which means newtons for force, seconds for time, and kilograms for mass.

Check Point 4.2: No, the force and motion equation only tells us the *change* in the velocity. We don't even know whether it is speeding up or slowing down, because we aren't told which way the object is moving.

Check Point 4.3: The change in motion is 2.5 m/s, half of what it was with the 10 N net force, since the magnitude of the net force is half of what it was when the change in velocity was 5 m/s. We don't need to know the mass since it is the same object, and thus the same mass in each case.

Check Point 4.4: 2000 m/s; it is greater because its mass is smaller

Check Point 4.5: The change in velocity would be the same as before, 7.5 m/s northward

Check Point 4.6: 200 s

Check Point 4.7: 50 s

Check Point 4.8: The light Ping-pong ball. Since Δt and m are both on the right side of the force and motion equation, with Δt in the numerator and m in the denominator, they must be directly proportional (i.e., their quotient must remain the same, since all the other quantities stay the same). That means that the more massive object (the bowling ball) will take longer to stop (since the net force on each is the same and both were initially moving with the same speed).

5. Forces as Interactions

Check Point 5.1: yes, yes, because when two objects interact, they exert forces on each other.

Check Point 5.2: Because people don't have forces. Forces are due to how someone interacts with something else. The force can't be assigned to one or the other.

Check Point 5.3: No, as they don't occur at the same time. The law of interactions states that the force exerted on my brother's shoulder (due to me) as I push him is equal to the force I feel on my hand (due to him) *while* I am in the process of pushing him.

Check Point 5.4: Westward; The law of interactions

Check Point 5.5: They are equal. The law of interactions.

Check Point 5.6: (a) equal, (b) equal, (c) The law of interactions

Check Point 5.7: 0.3 m/s

6. Collisions

Check Point 6.1: (c) The car's mass is less. The forces must have equal magnitudes (law of interactions) and the time must be the same (same interaction).

Check Point 6.2: 1 m/s

Check Point 6.3: 12.5 m/s eastward

7. Acceleration and Velocity

Check Point 7.1: (a) Because the distance the car moves during each time interval is more than the others. (b) The middle car. (c) At four seconds. (d) They all have a zero acceleration.

Check Point 7.2: (a) The car (the fan cart is not moving) (b) The fan cart (it has to be moving faster in order to catch up) (c) The fan cart (the car is not accelerating) (d) The fan cart (the car is not accelerating)

$$\vec{v}_{\text{avg}} = \frac{\Delta\vec{s}}{\Delta t} \tag{7.1}$$

$$\vec{a}_{\text{avg}} = \frac{\Delta\vec{v}}{\Delta t} \tag{7.2}$$

Check Point 7.3: Yes. Walking down the sidewalk at a constant speed and direction, or driving down a straight street are two such examples.

Check Point 7.4: 5 m/s

Check Point 7.5: No, it does not mean it is moving at a speed of 5 m/s. It is not possible say how fast the object is traveling. All we know is that it is accelerating.

Check Point 7.6: Unless you are driving the Tesla Model S Plaid, your acceleration is less than the Tesla.

Check Point 7.7: If it is speeding up at 5 m/s^2, that means the speed is increasing by 5 m/s every second. Multiply by three seconds to get a change of 15 m/s. If it was initially moving at 20 m/s, then three seconds later it would be moving at 35 m/s.

Check Point 7.8: If it is slowing down at 5 m/s^2, that means the speed is decreasing by 5 m/s every second. Multiply by three seconds to get a change of 15 m/s. If it was initially moving at 20 m/s, then three seconds later it would be moving at 5 m/s.

Check Point 7.9: Westward at 1 mi/min

Check Point 7.10: In physics, both are accelerations. The only difference is the direction of the acceleration. For (a) it is northward while for (b) it is southward.

$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m} \tag{7.3}$$

Check Point 7.11: Both the acceleration and the net force are directed southward (opposite the direction of motion), since the object is slowing down.

8. Distance

Check Point 8.1: The initial velocity. Consider, for example, an object that starts with a speed of 10 m/s and slows down to 5 m/s. The average must be somewhere between 10 m/s and 5 m/s.

Check Point 8.2: Since the acceleration is constant, the average velocity is equal to the midrange between the initial velocity (10 m/s northward) and the final velocity (16 m/s northward), which means the average velocity is 13 m/s northward. The average acceleration, on the other hand, is the difference in velocity (6 m/s northward) divided by the elapsed time (3 s), which means the average acceleration is 2 m/s^2 northward.

Check Point 8.3: 60 m

Check Point 8.4: (a) 1.5 s, (b) 1.5 minutes

Check Point 8.5: At an acceleration of 2 m/s^2, the object would speed up to 16 m/s by the end of the three seconds (a change of 6 m/s during the 3 seconds). The average of 10 and 16 is 13, so the average speed is 13 m/s. An object moving at that speed would travel 39 m in 3 s (multiply 13 by 3).

Check Point 8.6: Use the force and motion equation to get an acceleration of 5 m/s^2 (northward), which means it is speeding up (since it is being pushed in the direction of motion). At an acceleration of 5 m/s^2, the object would speed up to 20 m/s by the end of the two seconds (a change of 10 m/s during the two seconds). The average of 10 and 20 is 15, so the average speed is 15 m/s. An object moving at that speed would travel 30 m in 2 s (multiply 130 by 2).

Check Point 8.7: (a) difference, (b) average

Check Point 8.8: The box is slowing down, since the force is rightward while the box is moving leftward. The acceleration is 15 m/s^2 (use force and motion equation; divide net force by mass). During the 0.2 s, that means the object slows down by 3 m/s (multiply acceleration by the time). Since it started at 4 m/s, that means it is going 1 m/s by the end of the 0.2 s. Since the net force is constant, so is the acceleration and so the average speed is midway between 1 m/s and 4 m/s. That would give an average speed of 2.5 m/s. At that speed, for 0.2 s, an object would travel 0.5 m (multiply average speed by the time).

9. Turning Around

Check Point 9.1: (a) Joe's force needs to be toward Moe, since the ball slowed down as it was moving toward Joe (opposite Joe's force). (b) Joe's force continues to be toward Moe, since the ball is changing directions from moving toward Joe to moving toward Moe. (c) Joe's force continues to be toward Moe, since the ball is moving toward Moe and speeding up.

Check Point 9.2: The change in velocity is 10 m/s in this case. Divide by 5 s to get an acceleration of 2 m/s^2.

Check Point 9.3: Northward.

Check Point 9.4: The change is 7.5 m/s in all three cases but the final velocity is 12.5 m/s northward in (a), 2.5 m/s southward in (b) and 2.5 m/s northward in (c).

Check Point 9.5: (a) 35 m/s eastward, (b) 12.5 m/s eastward

Check Point 9.6: 40 miles eastward

Check Point 9.7: Divide the net force by the mass to get an acceleration is 4 m/s^2, slowing down since the net force is opposite the motion. Multiply by 3 seconds to get a change in velocity equal to 12 m/s. This means the object slowed to a stop (change of 3 m/s) and then sped up to 9 m/s (for a total change of 12 m/s) in the opposite direction. The average of 3 m/s eastward and 9 m/s westward is 3 m/s westward (use a number line if needed). Over three seconds that corresponds to a displacement of 9 m westward.

10. Graphs

Check Point 10.1: A little more than 6 m (see dotted line on graph).

Check Point 10.2: The middle car (indicated by line "b") is furthest to the right, 2 meters in front of the top car and 4 meters in front of the bottom car.

Check Point 10.3: The middle car (indicated by line "b") is traveling fastest because it has a velocity of +4 m/s whereas the others have a velocity of +2 m/s and +1 m/s.

Check Point 10.4: No. Object F is actually moving as can be see by the fact that it doesn't remain at zero. It just happens to be at that location at that particular time.

Check Point 10.5: (a) objects B and D, (b) No, object F's velocity is positive during the entire three seconds

Check Point 10.6: (a) Object K. Objects J's velocity is negative except at time zero (when the its velocity is zero). Object K's velocity is negative only before 2 s. (b) Yes, object L's velocity is zero at 2 seconds.

Check Point 10.7: (a) Objects H and J. (b) No, object L's acceleration is positive during the entire 3 seconds.

Check Point 10.8: The net force is −5 N, or 5 N in the negative direction.

Check Point 10.9: (a) Objects B and D. (b) Lines B and D, (c) +10 m/s, (d) +10 m/s

Check Point 10.10: Both are equal to +10 m/s^2.

Check Point 10.11: (a) zero, (b) zero, (c) +30 m/s

11. Oscillations

Check Point 11.1: (a) At the equilibrium position, (b) no, since it is moving at that moment and so its inertia carries out away from the equilibrium position.

Check Point 11.2: Position (a)

Check Point 11.3: (a) -2 cm, (b) positive

Check Point 11.4: Positive

Check Point 11.5: 4 cm

Check Point 11.6: At 5 seconds.

Check Point 11.7: (a) One-half of a cycle, (b) all the way on the left, (c) $+2$ cm

12. The Law of Gravity

Check Point 12.1: The second phrase seems to imply that the force "belongs" to the sun rather than being a consequence of the object's interaction with the sun.

Check Point 12.2: They are equal in magnitude.

Check Point 12.3: Toward the center of Earth.

Check Point 12.4: (a) yes, (b) yes but it is very small because the stapler is not massive like Earth, (c) yes but it would still be very small because the stapler is not massive like Earth

Check Point 12.5: (a) magnetic force, (b) gravitational force

Check Point 12.6: Yes. However, there is *also* another force acting on the rock (due to me), pushing it upward.

$$|\vec{F}_{\mathrm{g}}| = G\frac{m_1 m_2}{r^2} \tag{12.1}$$

Check Point 12.7: G is equal to 6.67430×10^{-11} N·m^2/kg^2.

Check Point 12.8: Yes. The gravitational force on me by the ball is much, much less than the gravitational force on my by Earth. Even though the ball is much, much closer to me than Earth, the Earth is much, much more massive.

Check Point 12.9: You'll get the same value whether you assume I am on the surface or I am 2 meter above the floor, since 2 meters is so small compared to the radius of Earth. Be careful not to use 2 meters as r. It is the distance from me to the center of Earth (i.e., the radius of Earth plus 2 meters).

Check Point 12.10: Goes down by a factor of 1/9.

13. Gravitational Field Strength

$$|\vec{F}_{\mathrm{g}}| = m(9.8\ \mathrm{N/kg}) \tag{13.1}$$

Check Point 13.1: 2.94 N downward (see equation 13.1). The fact that the ball is moving is inconsequential.

$$|\vec{F}_{\mathrm{g}}| = mg \tag{13.2}$$

$$g = G\frac{M}{r^2} \tag{13.3}$$

Check Point 13.2: Less than 9.8 N/kg.

Check Point 13.3: The rock only

Check Point 13.4: Mass

Check Point 13.5: This depends on how big you are but a typical mass is between 50 and 150 kg.

Check Point 13.6: Yes, because the magnitude of the force is roughly the same on all sides of the object so the net effect is an insignificant force (unless the object is moving quickly through the air or the air is moving very quickly past the object).

14. Free Fall

Check Point 14.1: (a) Yes, (b) No

Check Point 14.2: Downward. The fact that it is moving is inconsequential.

Check Point 14.3: (a) 1.5 seconds, (b) 4.9 m/s downward

Check Point 14.4: (a) Yes. During free fall, the ball's acceleration is 9.8 m/s^2 downward. (b) No. During free fall the ball's velocity is constantly changing and does not have a single value.

Check Point 14.5: No. A free fall acceleration of 9.8 m/s^2 means that the velocity continues to change during the entire time the object is in free fall.

Check Point 14.6: Also 0.45 seconds since the way each ball speeds up is independent of the mass.

Check Point 14.7: zero (three seconds later it is back where it started; remember that the displacement is not the same as the total distance traveled)

Check Point 14.8: Because we need to use the average velocity, not the final velocity.

15. Gravity with Other Forces

Check Point 15.1: No, we can't tell. We can only tell that the forces are balanced and so the object isn't accelerating.

Check Point 15.2: (a) A contact force (due to the hand) and a gravitational force (due to Earth).
(b) A gravitational force (due to Earth).

Check Point 15.3: Upward. Technically, downward would also be normal, since normal means perpendicular.

Check Point 15.4: 39.2 N upward.

Check Point 15.5: No, since the surface force only has a non-zero value if the object is in contact with the surface.

Check Point 15.6: Greater.

Check Point 15.7: (a) The gravitational force, (b) 37.6 N

Check Point 15.8: The string is oriented vertically and since the string can only pull, not push, that means the force must be upward (as opposed to downward).

Check Point 15.9: (a) The gravitational force, (b) 9400 N upward

Check Point 15.10: Because the force due to the cable is not the only force acting on the elevator. There is also the gravitational force (due to Earth).

Check Point 15.11: The gravitational force on the box (due to Earth) is 980 N (multiply the mass by 9.8 N/kg). That means the force pulling upward must also be 980 N in order to keep the box at rest. Each rope can only hold 500 N by itself, so a single rope would break. However, with two ropes, the two forces could be 490 N each (below the 500 N) limit and still, together, equal 980 N.

Check Point 15.12: The one that is not scrunched up will reach its terminal speed first. They have the same mass, so the gravitational force is the same on both. However, the scrunched up one is more aerodynamic and thus has less drag. That means it has to go faster in order for the drag to balance the gravitational force. In other words, it has a higher terminal speed and, as such, will take longer to reach that state.

Check Point 15.13: The average would not be equal to 15 m/s because the velocity does not change uniformly from its initial value (zero) to its final value (30 m/s downward). Rather, it spends more time with values closer to the final value (suppose, for example, that the object reached terminal speed very quickly). That means the average will be closer to 30 m/s downward.

16. Projectile Motion

Check Point 16.1: The length is 0.3 m in both cases (each corresponds to a 0.1-second interval), as the horizontal motion does not change while the ball is in the air - it must be the same as it was on the table top.

Check Point 16.2: 0.4 m rightward (multiply the horizontal velocity by the time).

Check Point 16.3: 5 m rightward (multiply the horizontal velocity by the time).

Check Point 16.4: No. The object accelerates downward as it falls because there is a force pulling it downward.

Check Point 16.5: They will hit at the same time, since the horizontal motion has no bearing on the vertical motion.

Check Point 16.6: Use a value of zero. Since the problem asks for the *vertical* displacement, we need the initial value of the *vertical* velocity. The ball's velocity when it enters the air is the same as its velocity while on the table and it had no vertical motion while on the table.

Check Point 16.7: The answer would not change at all because the only difference is that the initial horizontal motion was 5 m/s instead of 3 m/s. All of the *vertical* quantities (force, initial velocity, etc.) remain the same as before.

Check Point 16.8: To find the *vertical* component of the initial velocity, we need the *vertical* component of displacement. In this case, the object started and ended at the same vertical height (i.e., on the ground). Thus, its *vertical* displacement was zero.

Check Point 16.9: The piano doesn't fall into the pool, regardless of the drag, as the piano will continue to move eastward as it falls. The only difference is whether it moves horizontally at 50 m/s (no drag) or somewhat less than that.

17. Motion Along Surfaces

Check Point 17.1: (a) Leftward, (b) There is no friction force in that case.

Check Point 17.2: Yes. Both force diagrams would have three arrows but for the box sliding down the ramp the one corresponding to the friction force would be directed up the ramp whereas for the box sliding up the ramp it would be directed down the ramp.

Check Point 17.3: (a) Without friction, my feet would slip backward. Friction opposes the slipping, so it must be directed forward, in the direction that I am moving.
(b) Conversely, when I try to stop, friction is directed backwards.

Check Point 17.4: Zero. The friction force only acts to keep the object at rest. If there is no force to balance, there is no friction force.

Check Point 17.5: No. If the two objects aren't touching, there is no friction force. Friction is a contact force.

$$|\vec{F}_{\mathrm{f,max}}| = \mu|\vec{F}_{\mathrm{n}}| \tag{17.1}$$

Check Point 17.6: (a) The friction would be 40-N, opposing the applied force and keeping the object at rest. This is possible because 40 N is less than the maximum possible (49 N).
(b) The friction would be 49-N, since that is the maximum possible. Since that is not enough to complete counter the applied force, the table starts to move.

Check Point 17.7: Yes.

Check Point 17.8: Anything between 0.41 and 0.51.

Check Point 17.9: (a) The surface repulsion force was needed in order to determine the friction force. The friction was needed because the force and motion equation only tells us the net force, which results from both the friction force and the applied force.

(b) The box wouldn't move at all. The 29.4 N value represents the *maximum* value that the friction force can have. If it doesn't need to be that high, it won't. It will just oppose our applied force such that the forces balance.

Check Point 17.10: No. What matters is that the velocity is constant, which means the forces are balanced.

18. Obtaining Component Values

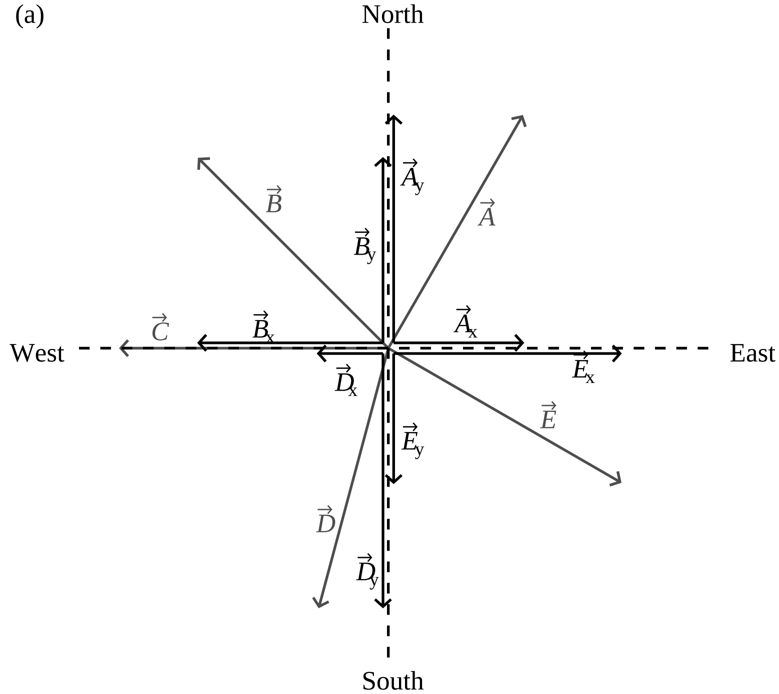
Check Point 18.1: (a) 50 degrees, (b) 110 degrees

$$A^2 = A_x^2 + A_y^2 \tag{18.1}$$

Check Point 18.2: 3.38 m/s

Check Point 18.3: (a) Eastward and southward, (b) The eastward component would be larger.

(a)



(b) No.

Check Point 18.4:

Check Point 18.5: (a) Yes, unless you picked a number that corresponded to 0, 90, 180 or 270 degrees. (b) No, unless you picked a number that corresponded to 0, 90, 180 or 270 degrees. The two component values will always be larger than or equal to one.

Check Point 18.6: 4.7 m/s (eastward) and 1.7 m/s (northward).

19. Applications in Two Dimensions

Check Point 19.1: The problem asked for the vertical displacement. For this situation, the vertical values are not influenced by the horizontal values.

Check Point 19.2: No. For one thing, that would make the imbalance even more southward than before. You can go through the math with the revised magnitude of force C to verify.

Check Point 19.3: One of the displacements is not aligned along the component directions.

Check Point 19.4: It is because each end of the string pulls on the arrow equally.

Check Point 19.5: They aren't equal because those aren't the only two forces acting vertically. There is also a component of my applied force.

Check Point 19.6: (a) 43.3 N upward, obtained via the friction equation (the coefficient is provided and the friction is obtained from using the law of force and motion in the horizontal).
(b) zero, because friction is always directed parallel to the surface, which would be horizontal in this case.
(c) 5 N upward, obtained by using trigonometry on the force due to the string provided in the problem.

Check Point 19.7: One can be solved sequentially because each expressions ends up only have one unknown, while the other has to be solved simultaneously because each quantity ends up depending on its own value.

20. Circular Motion

Check Point 20.1: (a) 8.2 m, (b) 5 s, (c) 3.3 m

Check Point 20.2: 1.6 m/s

Check Point 20.3: The ball would move to the left, without curving. Once the string is released, there are no horizontal forces acting on the ball and thus the ball cannot change directions – it must continue in the same direction it had just before the string was released.

Check Point 20.4: $a_{\text{circ,avg}}$ would be zero (since you aren't speed up or slowing down) but $\vec{a}$ would not be (it would be directed to the center of the circle since you are constantly turning).

Check Point 20.5: Toward the center of the circle, so that I can turn that way

Check Point 20.6: (e) Toward Earth's axis, since Earth spins about its axis

Check Point 20.7: Assuming Earth is a perfect sphere, g should greater at the poles than that at the equator because an object at the poles is not moving in a circle and thus there should be no difference between the local and global gravitational fields, meaning that the actual value of g would equal the 9.8205 N/kg value if Earth was a perfect sphere. Because of Earth's shape, the poles are actually closer to Earth's center and thus have a higher value of g (about 9.83 N/kg).

21. Rotational Motion

Check Point 21.1: 90 degrees

Check Point 21.2: How far an object has rotated (in terms of an angle; the angular displacement).

Check Point 21.3: $\omega_{\mathrm{avg}} = (\omega_{\mathrm{i}} + \omega_{\mathrm{f}})/2$.

Check Point 21.4: (a) 0.5 rev/s, (b) 0.8 rev/s, (c) 1.95 rev

Check Point 21.5: It is spinning at a rate of 1 rev/s (counter-clockwise) and its total angular displacement is 1 rev clockwise.

Because the angular acceleration is opposite its initial angular velocity, that means the disk is slowing down. At a rate of 1 rev/s^2, it takes 2 seconds for the disk to stop. The disk then spins the opposite way. The average angular velocity is 0.5 rev/s clockwise. At 3 seconds, that means its total angular displacement is 1.5 rev.

Check Point 21.6: Your picture should illustrate a slice that represents about one-quarter of the pizza, with your explanation based on the length of the "crust" being 1.5 times the length of the radius.

Check Point 21.7: There are π radians (i.e., about 3.1415927 radians)

22. Circular-Angular Relationships

Check Point 22.1: No. While the product is equal to an arc length, the angle needs to be in radians for the units to work out.

$$\left.\begin{array}{rcl} s_{\mathrm{circ}} & = & r\theta \\ v_{\mathrm{circ}} & = & r\omega \\ a_{\mathrm{circ}} & = & r\alpha \end{array}\right\} \text{angle in radians} \tag{22.1}$$

Check Point 22.2: 6 m counter-clockwise,

$$\left.\begin{array}{rcl} v_{\mathrm{circ}} & = & (2\pi r)/T \\ a_{\mathrm{cent}} & = & (2\pi v_{\mathrm{circ}})/T \end{array}\right\} \text{for uniform circular motion only} \tag{22.2}$$

Check Point 22.3: 0.25 m/s^2

Check Point 22.4: 7.5 N

Check Point 22.5: Even though the surface of the road is banked, you are still moving in a horizontally-oriented circle, with the center of that horizontally-oriented circle is at the same "height" of the car. Thus, the center of the circle is to the left, and that direction is not parallel to the road because the road is banked and not horizontal. If the road was flat (level with horizontal) then the inward direction *would* be parallel to the road but that isn't the case here.

Check Point 22.6: A larger radius would be needed. Lowering the friction would lower the net force acting on the car. With a lower force, there would need to be a lower acceleration. To get that lower acceleration, with the same speed, one would need to increase the period. The only way to do that, with the same speed, is to increase the radius.

Check Point 22.7: 1.99×10^{30} kg (same as that given in the supplemental readings)

23. Predicting Rotational Motion

Check Point 23.1: (a) We use torque and rotational inertia. (b) No, the units will not be the same as the units for force and mass.

Check Point 23.2: (a) Arrows B and C, (b) arrows B and C; this is just a different way of saying the same thing

Check Point 23.3: The greater the distance from the hinges that the force acts, the greater the torque for a given force

$$\tau = F_{\text{circ}} r \tag{23.1}$$

Check Point 23.4: (a) 4 N·m clockwise, (b) zero

Check Point 23.5: At (d) the force would have to be 20 N rightward. At (e) the force would have to be 40 N rightward.

Check Point 23.6: Counter-clockwise

Check Point 23.7: No, an object's rotational inertia doesn't depend on whether the object is spinning or not. The hoop's rotational inertia around the axis in (b) would be smaller, regardless of the angular velocity, simply because the hoop's mass is closer, in general, to the axis in (b) than to the axis in (a).

Check Point 23.8: (a) No, it depends on the mass. With identical masses, the hoop has a greater rotational inertia, but as one increases the mass of the disk, its rotational inertia increases also.
(b) No, the disk spun like a top will have a smaller rotational inertia, since a greater portion of it will be close to the rotation axis, just like the hoops shown in the book.

$$\Delta\omega = \frac{\tau_{\text{net}}}{I}\Delta t \tag{23.2}$$

Check Point 23.9: 0.1 s

24. Balance

Check Point 24.1: Heavy ones on bottom and light ones on top, as that would produce the lowest center of gravity.

Check Point 24.2: The gravitational force is 19.6 N (multiply the mass by 9.8 N/kg) and we can treat it as acting at the plank's center of gravity, which is 0.9 m from the pivot. Multiply the gravitational force by the distance to the pivot to get 17.64 $\mathrm{N \cdot m}$, counter-clockwise.

Check Point 24.3: The three forces pushing upward, as they are associated with counter-clockwise torques, with magnitude equal to 1.225 $\mathrm{N \cdot m}$.

Check Point 24.4: The gravitational force on the plank is 19.6 N (multiply the mass by 9.8 N/kg) and we can treat it as acting at the plank's center of gravity, which is 0.4 m from the pivot. Multiply the gravitational force by the distance to the pivot to get 7.84 $\mathrm{N \cdot m}$, clockwise. To balance that, the torque associated with the gravitational force on the box must be 7.84 $\mathrm{N \cdot m}$, counter-clockwise. Since the box is 0.5 m from the pivot, divide by 0.5 m to get 15.68 N (as the gravitational force) then divide by 9.8 N/kg to get 1.6 kg (as the mass of the box).

Check Point 24.5: (a) Case 3 is the only balanced case. (b) For case 1, the torques are 0.686 N·m (distance if 35 cm from pivot) and 0.196 N·m (distance is 20 cm from pivot), both counter-clockwise. For case 2, the torques are both 0.294 N·m counter-clockwise (so they don't cancel). For case 3, one torque is 0.294 N·m counter-clockwise and the other is 0.294 N·m counter-clockwise. Remember to use the distance to the pivot and keep track of clockwise or counter-clockwise.

25. Work and Kinetic Energy

Check Point 25.1: (b) The object is slowing down because the net force is opposite its motion.

Check Point 25.2: It must be at its original location.

$$W = F_{\|}\Delta s \tag{25.1}$$

Check Point 25.3: No, since the motion is perpendicular to the gravitational force. In this case, the bottle slows down because the friction force.

$$\Delta E_{\mathrm{k}} = W \tag{25.2}$$

Check Point 25.4: No. Negative work means that the kinetic energy has decreased (a negative change in kinetic energy), and the object has slowed down.

$$E_{\mathrm{k}} = \tfrac{1}{2}mv^2 \tag{25.3}$$

Check Point 25.5: $12\ \mathrm{kg} \cdot \mathrm{m}^2/\mathrm{s}^2$

Check Point 25.6: 12 J

Check Point 25.7: 3 m/s

Check Point 25.8: 4.12 m/s

Check Point 25.9: The work done in both cases is positive since the gravitational force and displacement are both downward. Multiply the force magnitude (4.9 N; multiply mass by 9.8 N/kg) by the displacement magnitude (1 m) to get the work done: 4.9 J. Add to the initial kinetic energy (4 J; use $\frac{1}{2}mv^2$) to get a final kinetic energy of 8.9 J. The answer is the same for both parts because the initial kinetic energy is the same and the displacement is the same.

Check Point 25.10: From the definition of kinetic energy ($\frac{1}{2}mv^2$), we know that the kinetic energy decreased from 9 J to zero (using speeds of 3 m/s and zero, respectively), which means that $F_f \Delta s$ must equal 9 J. Since F_f is equal to 10 N, that means that Δs must equal 0.9 m.

Check Point 25.11: 10.2 m

Check Point 25.12: 6.25 m

Check Point 25.13: It will go nine times further. The speed is three times as much so the speed squared would be three squared (or nine) times as much.

Check Point 25.14: (a) 80 J, (b) 80 J

Check Point 25.15: 87 J (this corresponds to a speed of 5.9 m/s)

Check Point 25.16: 6.1×10^4 J (this corresponds to a speed of 11 m/s if you solve for the speed)

Check Point 25.17: (a) 1.2×10^4 J, (b) no, as it doesn't have the 4.9×10^4 J that the gravitational energy will remove as it travels upward.

Check Point 25.18: (a) 0.46 J, (b) zero (since the height is the same as where it started)

26. Conservation of Energy

Check Point 26.1: No. Your energy can change if there is a corresponding but opposite change in objects that you interact with.

Check Point 26.2: (a) Yes, (b) No

Check Point 26.3: Decrease

Check Point 26.4: No. The amount of energy in your house could change if there is a corresponding but opposite change in the region surrounding the house.

$$P = \frac{\Delta E}{\Delta t} \tag{26.1}$$

Check Point 26.5: 2.16×10^5 J

Check Point 26.6: It increases

$$E_{\text{rot}} = \tfrac{1}{2} I \omega^2. \tag{26.2}$$

Check Point 26.7: 19 J

Check Point 26.8: (a) with the objects are far apart, (b) with the objects close together

Check Point 26.9: (a) decrease, (b) increase, (c) the gravitational energy didn't change, the kinetic energy decreased and the thermal energy increased

Check Point 26.10: (a) stay the same, (b) increase, (c) decrease

Check Point 26.11: (a) same, because the size and mass don't affect the speed (the greater mass means the gravitational force is greater but it also needs a greater force to accelerate; the greater size means the rotational mass is greater but it can spin slower and still keep up with a smaller cylinder), (b) the hollow ball would be slower because a greater percentage of its mass is farther from the center (compared to a solid ball)

Check Point 26.12: 0.025 Cal

Check Point 26.13: (a) No, friction does no work on the car. The energy transfer is internal to the car itself. (b) yes, friction does negative work on the car in this case.

27. Conservation of Momentum

$$\vec{p} = m\vec{v} \quad (27.1)$$

Check Point 27.1: 6×10^4 kg · m/s northward

$$\Delta(\text{momentum}_\text{A}) = -\Delta(\text{momentum}_\text{B}) \quad (27.2)$$

Check Point 27.2: (C) is only true if the two objects have the same mass

Check Point 27.3: It got transferred to the clay/wall system. The wall is part of Earth and Earth is so massive that an increase of 5 kg·m/s of momentum corresponds to hardly any change in speed at all.

Check Point 27.4: 12.5 m/s eastward

Check Point 27.5: 0.2 m/s

$$\text{angular momentum} = I\omega. \quad (27.3)$$

Check Point 27.6: (a) 0.893 rev/s, (b) no

Check Point 27.7: (a) Clockwise, because Earth spins clockwise as seen from someone looking down on the Southern Hemisphere. (b) No, because the sink is so small and Earth's rotation rate so small that the change in r would not be sufficient to result in a significant change in *omega* (the rotation rate).

Check Point 27.8: 6.67 m/s (rightward)

Check Point 27.9: Yes, it is zero since the momentum of one ball must be equal and opposite to the momentum of the other.