Answers to conceptual integrated science end-of-chapter questions chapter 1: abou...

Science, Physics

Answers to Conceptual Integrated Science End-of-Chapter Questions Chapter 1: About Science Answers to Chapter 1 Review Questions 1 The era of modern science in the 16th century was launched when Galileo Galilei revived the Copernican view of the heliocentric universe, using experiments to study nature’s behavior. 2 In Conceptual Integrated Science, we believe that focusing on math too early is a poor substitute forconcepts. 3 We mean that it must be capable of being proved wrong. 4 Nonscientiï¬�c hypotheses may be perfectly reasonable; they are nonscientiï¬�c only because they are not falsiï¬�able–there is no test for possible wrongness. Galileo showed the falseness of Aristotle’s claim with a single experiment–dropping heavy and 5 lightobjects from the Leaning Tower of Pisa. 6 A scientiï¬�c fact is something that competent observers can observe and agree to be true; a hypothesis is an explanation or answer that is capable of being proved wrong; a law is a hypothesis that has been tested over and over and not contradicted; a theory is a synthesis of facts and well-tested hypotheses. In everyday speech, a theory is the same as a hypothesis–a statement that hasn’t been tested. 7 8 Theories grow stronger and more precise as they evolve to include new information. 9 The term supernatural literally means “ above nature. " Science works within nature, not above it. 10 They rely on subjective personal experience and do not lead to testable hypotheses. They lie outside the realm of science. Science, art, and religion can work very well together; like strings on a guitar, when played 11 together, the chord they produce can be a chord of profound richness. 12 Science is concerned with gathering knowledge and organizing it. Technology lets humans use that knowledge for practical purposes, and it provides the instruments scientists need to conduct their investigations. 13 Chemistry builds on physics by telling us how matter is put together, how atoms combine to form molecules, and how the molecules combine to make the materials around us. Biology is more complex than physical science (physics and chemistry), because it involves matter that is alive and, therefore, engaged in complex biochemical processes. 14 Integrated science is valuable because the real-life phenomena we are interested in typically involve principles from more than one branch of science; put another way, we study integrated science because the world is integrated. Answers to Chapter 1 Integrated Science Concepts Chemistry and Biology: An Investigation of Sea Butterï¬, ies 1 The disciplines of biology and chemistry are needed to understand the behavior of the Antarctic amphipod. 2 The control used in the investigation was the pellets fed to the predator ï¬�sh that were not treated with sea-butterï¬, y extracts. The control was needed to see whether the chemical deterrent isolated from the sea butterï¬, y deterred the predator ï¬�sh. 3 McClintock and Baker's hypothesis was that amphipods carry sea butterï¬, ies because sea butterï¬, ies pro-duce a chemical that deters a predator of the amphipod. This is a scientiï¬�c hypothesis because it would be proven wrong if the secreted chemical were found to not deter amphipod predators. Answers to Chapter 1 Exercises 1. Are the various branches of science separate or do they overlap? Give several examples to support your answer. The various branches of science overlap as we see by the existence of these hybrid ï¬�elds: astrobiology; biochemistry; biophysics; ecology (biology and earth science); geochemistry, etc. 2. What do science, art, and religion have in common? How are they different? Science, art, and religion are all searches for deeper understanding of the world. The differences can be summed up as follows: science asks how, art asks who, and religion asks why. The most important difference between religion and science is that religion asks why and science asks how. 3. Can a person’s religious beliefs be proven wrong? Can a person’s understanding of a particular scientiï¬�c concept be proven wrong ? No; religion is a subjective area of study so that it cannot be wrong in the sense of being provably false. However, religions that do claim to be based on a factual knowledge of the physical world that is prov-ably false can be said to be logically ï¬, awed. A person can certainly be wrong in their understanding of scientiï¬�c concepts–experiments and observation often can correct such misunderstandings. 4. In what sense is science grand and breathtaking? In what sense is it dull and painstaking? Science is grand and breathtaking in its remarkable insights into the mechanisms of the universe; it is dull and painstaking in that careful, disciplined, and sometimes even tedious research is needed to reach those conclusions. 5. How is the printing press like the Internet in terms of the history of science? The printing press greatly accelerated the progress of science by facilitating communication– suddenly practitioners of science could collaborate across distance. The Internet takes communication to a new level because it is so fast, open, and accessible. Solutions to Chapter 1 Problems 1. The more candy bars you add to your diet per day, the more weight you gain (all other factors such as the amount of exercise you get being equal). Is this an example of a direct proportion or an inverse proportion? Direct proportion 2. State the above relation in mathematical form. (Hint: Don’t forget to use a proportionality constant with appropriate units.) We set W weight gain/week and C candy bars eaten/week. Then the more candy bars you add to your diet per week, the more weight you gain per week is expressed like this: W C, where is the proportionality constant. Because W has units of lb/week and C has units of candy bars/week, W/C has units of lb/candy bars. Given values for W and C, one can solve for the numerical value of . For example, if eating seven candy bars per week results in a 1-lb per week weight gain, 1/7 lb/candy bars. 3. What is an example of an inverse proportion that you have observed in your daily life? Express it in mathematical form. Sample answer: The more you practice shooting a basketball (P), the fewer shots you miss (m); P k/m. Chapter 2: Describing Motion Answers to Chapter 2 Review Questions 1 Aristotle classiï¬�ed motion into two kinds: natural motion and violent motion. 2 Aristotle believed forces were necessary. It was Galileo who later refuted this idea and established the concept of inertia. 1 Galileo discredited the idea that heavy objects fall faster than light ones, and that a force is necessary to maintain motion. 2 Experiment. In conducting experiments, Galileo ushered in the age of modern science. 3 Inertia. 4 Weight depends on gravity, while mass does not. 5 Your weight is greater on the Earth because of its stronger gravity. Your mass is the same at all locations. 6 Newtons for weight, kilograms for mass. 7 Less. 8 Any amount of water has the same density. The net force on the box is 10 N to the right. 9 10 Both magnitude and direction. 11 Tension. 12 20 N. 13 F 0 means that the vector sum of all the forces that act on an object in equilibrium equal zero. Forces cancel. 14 Because it acts at right angles to the surface. Normal is another term for " right angle. " 15 The same. You actually read the support force by the scale, which is the same as your weight when the scale is stationary. 16 It is in equilibrium if its velocity is not changing. 17 Because it slides in equilibrium (constant velocity), we know the friction must be equal and opposite to our push. That way, they cancel, and the crate slides without changing speed. 18 Opposite, always. 19 To the left. 20 Yes, opposite to your push, just enough so that F 0. 21 speed distance/time 22 Velocity involves both magnitude (speed) and direction. Speed involves only magnitude. 23 Instantaneous speed. 24 You can be at rest relative to the Earth but moving at 100, 000 km/h relative to the sun. 25 acceleration change in velocity/time interval 26 Acceleration is zero, and the net force is therefore zero. 27 It appears once for the unit of velocity, and again for the time during which velocity changes. 28 It decreases by 10 m/s each second. Answers to Chapter 2 Multiple-Choice Questions 1c, 2d, 3b, 4a, 5a Answers to Chapter 2 Integrated Science Concepts Biology: Friction Is Universal 1 rub Synovial ï¬, uid is a lubricant. It protects the bones against the wearing effects of friction–bones against the lubricating synovial ï¬, uid instead of against each other. 2 Possible examples include physics—air resistance; chemistry—lubricants; biology—ï¬�ngerprints; earthscience—earthquakes; atronomy—meteors. 3. One might argue that friction prevents earthquakes in the sense that large blocks of rock are held still because of the friction between them. However, friction truly is implicated as a cause of earthquakes because if there were no friction, the blocks of rock could move along one another smoothly, never building up the strain that is released violently and suddenly in an earthquake. Biology: Hang Time 1 2 Your speed is zero at the top of your jump. Length of legs and strength of leg muscles. Answers to Exercises 1. A bowling ball rolling along a lane gradually slows as it rolls. How would Aristotle interpret this observation? How would Galileo interpret it? Aristotle would likely say the ball slows to reach its natural state. Galileo would say the ball is encountering friction, an unbalanced force that slows it. 2. What Aristotelian idea did Galileo discredit in his fabled Leaning Tower of Pisa experiment? With his inclined plane experiments? The Leaning Tower experiment discredited the idea that heavy things fall proportionally faster. The incline plane experiments discredited the idea that a force was needed for motion. 3. What physical quantity is a measure of how much inertia an object has? Mass. 4. Does a dieting person more accurately lose mass or lose weight? Mass. To lose weight, the person could go to the top of a mountain where gravity is less. But the amount of matter would be the same. 3 5. One cm of lead has a mass of 11. 3 g. What is its density? Two grams of aluminum has a mass of 5. 4 g. What is the density of aluminum? 3 3 3 The density of lead is 11. 3 g/cm . The density of aluminum is 5. 4 g/2 cm 2. 7 g/cm . 6. Which has the greater density–5 kg of lead or 10 kg of aluminum? Density is a ratio of weight or mass per volume, and this ratio is greater for any amount of lead than for any amount of aluminum, so 5 kg of lead has a greater density than 10 g of aluminum. 7. Consider a pair of forces, one with a magnitude of 25 N, and the other 15 N. What maximum net force is possible for these two forces? What is the minimum net force possible? Maximum, 25 N 15 N 40 N. Minimum, 25 N 15 N 10 N. 8. The sketch shows painter’s scaffold in mechanical equilibrium. The person in the middle weighs 250 N, and the tensions in each rope are 200 N. What is the weight of the scaffold? From F 0, the upward forces are 400 N and the downward forces are 250 N weight of the scaf-fold. The scaffold must weigh 150 N. 9. A different scaffold that weighs 300 N supports two painters, one 250 N and the other 300 N. The reading in the left scale is 400 N. What is the reading in the right scale? From F 0, the upward forces are 400 N tension in right scale. This sum must equal the downward forces of 250 N 300 N 300 N. Arithmetic shows the reading on the right scale is 450 N. 10. Can an object be in mechanical equilibrium when only a single force acts on it? Explain. No, not unless the force is zero. A net force will accelerate the object. 11. Nellie Newton hangs at rest from the ends of the rope, as shown. How does the reading on the scale compare to her weight? Each scale shows half her weight. 12. Harry the painter swings year after year from his bosun's chair. His weight is 500 N, and the rope, unknown to him, has a breaking point of 300 N. Why doesn't the rope break when he is supported? One day Harry is painting near a ï¬, agpole, and, for a change, he ties the free end of the rope to the ï¬, agpole instead of to his chair as shown to the right. Why did Harry end up taking his vacation early? In the left ï¬�gure, Harry is supported by two strands of rope that share his weight (like the little girl in the previous exercise). So, each strand supports only 250 N, below the breaking point. Total force up supplied by ropes equals weight acting downward, giving a net force of zero and no acceleration. In the right ï¬�gure, Harry is now supported by one strand, which for Harry's well-being requires that the tension be 500 N. Because this is above the breaking point of the rope, it breaks. The net force on Harry is then only his weight, giving him a downward acceleration of g. The sudden return to zero velocity changes his vacation plans. 13. Consider the two forces acting on the person who stands still, namely, the downward pull of gravity and the upward support of the ï¬, oor. Are these forces equal and opposite? Yes, the forces are equal and opposite and cancel to zero putting the person in equilibrium. 14. Can we accurately say that if something moves at constant velocity that there are no forces acting on it? Explain. No, we cannot, for there may well be forces that cancel to zero. We can say no net force acts on it. 15. At the moment an object tossed upward into the air reaches its highest point, is it in equilibrium? Defend your answer. No, for the force of gravity acts on the object. Its motion is undergoing change, as a moment later should be evident. 16. If you push horizontally on a crate and it slides across the ï¬, oor, slightly gaining speed, how does the friction acting on the crate compare with your push? If the crate speeds up, then your force is greater than the force of friction. 17. What is the impact speed when a car moving at 100 km/h bumps into the rear of another car traveling in the same direction at 98 km/h? Relative speed is 2 km/h. 18. Harry Hotshot can paddle a canoe in still water at 8 km/h. How successful will he be at canoeing upstream in a river that ï¬, ows at 8 km/h? Not very, for his speed will be zero relative to the land. 19. A destination of 120 miles is posted on a highway sign, and the speed limit is 60 miles/hour. If you drive at the posted speed, can you reach the destination in 2 hours? Or more than 2 hours? More than 2 hours, for you cannot maintain an average speed of 60 miles/hour without exceeding the speed limit. You begin at zero, and end at zero, so even if there’s no slowing down along the way you’ll have to exceed 60 mi/h to average 60 mi/h. So it will take you more than 2 hours. 20. Suppose that a freely falling object were somehow equipped with a speedometer. By how much would its speed reading increase with each second of fall? 10 m/s. 21. Suppose that the freely falling object in the preceding exercise were also equipped with an odometer. Would the readings of distance fallen each second indicate equal or unequal distances of fall for successive seconds? Explain. Distance increases as the square of the time, so each successive distance covered is greater than the preceding distance covered. 22. When a ball player throws a ball straight up, by how much does the speed of the ball decrease each second while ascending? In the absence of air resistance, by how much does it increase each second while descending? How much time is required for rising compared to falling? The ball slows by 10 m/s each second and gains 10 m/s when descending. The time up equals the time down if air resistance is nil. 23. Someone standing at the edge of a cliff (as in Figure 2. 24) throws a ball straight up at a certain speed and another ball straight down with the same initial speed. If air resistance is negligible, which ball has the greater speed when it strikes the ground below? Both hit the ground with the same speed (but not in the same time). 24. For a freely falling object dropped from rest, what is its acceleration at the end of the 5th second of fall? The 10th second? Defend your answer (and distinguish between velocity and acceleration). 2 Acceleration is 10 m/s , constant, all the way down. (Velocity, however, is 50 m/s at 5 seconds, and 100 m/s at 10 seconds.) 25. Two balls, A and B, are released simultaneously from rest at the left end of the equal-length tracks A and B as shown. Which ball will reach the end of its track ï¬�rst? The ball on B ï¬�nishes ï¬�rst, for its average speed along the lower part as well as the down and up slopes is greater than the average speed of the ball along track A. 26. Refer to the tracks. (a) Does ball B roll faster along the lower part of track B than ball A rolls along track A? (b) Is the speed gained by ball B going down the extra dip the same as the speed it loses going up near the right-hand end–and doesn't this mean the speed of balls A and B will be the same at the ends of both tracks? (c) On track B, won't the average speed dipping down and up be greater than the average speed of ball A during the same time? (d) So overall, does ball A or ball B have the greater average speed? (Do you wish to change your answer to the previous exercise?) (a) Average speed is greater for the ball on track B. (b) The instantaneous speed at the ends of the tracks is the same, because the speed gained on the down-ramp for B is equal to the speed lost on the up-ramp side. (Many people get the wrong answer for Exercise 25, because they assume that because the balls end up with the same speed that they roll for the same time. Not so.) Solutions to Chapter 2 Problems 1. Find the net force produced by a 30-N force and a 20-N force in each of the following cases: (a) Both forces act in the same direction. (b) The two act in opposite directions. (a) 30 N 20 N 50 N. (b) 30 N 20 N 10 N. 2. A horizontal force of 100 N is required to push a box across a ï¬, oor at constant velocity. (a) What is the net force acting on the box? (b) How much is the friction force that acts on the box? (a) Net force is zero (because velocity is constant!). (b) Friction 100 N. 3. A ï¬�reï¬�ghter with a mass of 100 kg slides down a vertical pole at constant speed. What is the force of friction provided by the pole? 2 From F 0, friction equals weight, mg, (100 kg)(9. 8 m/s) 980 N. 4. The ocean's level is currently rising at about 1. 5 mm per year. At this rate, in how many years will sea level be 3 meters higher than now? dd From v , t . tv 3000 mm We convert 3 m to 3000 mm, and t 2000 years. 1. 5 mm/year 5. A vehicle changes its velocity from 90 km/h to a dead stop in 10 s. Show that its acceleration in doing 2 so is 2. 5 m/s . change in velocity 90 km/h a 2. 5 km/h s. time interval 10 s(The vehicle decelerates at 2. 5 km/h s.) 6. A ball is thrown straight up with an initial speed of 40 m/s. (a) Show that its time in the air is about 8 seconds. (b) Show that its maximum height, neglecting air resistance, is about 80 m. Because it starts going up at 40 m/s and loses 10 m/s each second, its time going up is 4 seconds. Its time returning is also 4 seconds, so it's in the air for a total of 8 seconds. Distance up (or down) is 1/2 2 2 gt 5 4 80 m. Or from d vt, where average velocity is (40 0)/2 20 m/s, and time is 4 seconds, we also get d 20 m/s 4 s 80 m. 1 Extend Table 2. 2 (which gives values of from 0 to 5 s) to 0 to 10 s, assuming no air resistance. 8. A ball is thrown with enough speed straight up so that it is in the air several seconds. (a) What is the velocity of the ball when it reaches its highest point? (b) What is its velocity 1 s before it reaches its highest point? (c) What is the change in its velocity during this 1-s interval? (d) What is its velocity 1 s after it reaches its highest point? (e) What is the change in velocity during this 1-s interval? (f) What is the change in velocity during the 2-s interval? (Caution: velocity, not speed!) (g) What is the acceleration of the ball during any of these time intervals and at the moment the ball has zero velocity? (a) The velocity of the ball at the top of its vertical trajectory is instantaneously zero. (b) One second before reaching its top, its velocity is 10 m/s. (c) The amount of change in velocity is 10 m/s during this 1-second interval (or any other 1second interval). (d) One second after reaching its top its, velocity is 10 m/s–equal in magnitude but oppositely directed to its value 1 second before reaching the top. (e) The amount of change in velocity during this (or any) 1-second interval is 10 m/s. (f) In 2 seconds, the amount of change in velocity, from 10 m/s up to 10 m/s down, is 20 m/s (not zero!) 2 (g) The acceleration of the ball is 10 m/s before reaching the top, when reaching the top, and after reaching the top. In all cases, acceleration is downward, toward the Earth. Time (in seconds) 0 1 2 3 4 5 6 7 8 9 10 Velocity (in meters/second) 0 10 20 30 40 50 60 70 80 90 100 Distance (in meters) 0 5 20 45 80 125 180 245 320 405 500 Chapter 3: Newton's Laws of Motion Answers to Chapter 3 Review Questions 1 Every object continues in a state of rest, or in a state of motion in a straight line at constant speed, unless it is compelled to change that state by forces exerted upon it. 2 Straight line. 3. The acceleration produced by a net force on an object is directly proportional to the net force, is in the same direction as the net force, and is inversely proportional to the mass of the object. 2 Acceleration is directly proportional to force. As an example, if the net force on a body is doubled, the acceleration doubles also. 2 No change in acceleration. 2 2 10 m/s . 2 When in free fall, the ratio of weight/mass is the same for all objects. 2 Zero. 2 Air resistance depends on speed and surface area. 2 The greater weight of the heavier person compared to air drag produces a greater acceleration until terminal velocity is reached. 2 Two. 2 When you push on the wall, the wall pushes on you. It is the force of the wall on your ï¬�ngers that bends them. 2 He can't exert any more force on the tissue paper than the tissue paper can exert on him. The tissue paper has insufï¬�cient inertia for a great force. 2 Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the ï¬�rst. 2 Ball against the bat. 2 Simultaneously. 2 Each of the equal forces acts on different masses. 2 An external force is needed to accelerate a system. 2 Force, velocity, and acceleration are vector quantities. Time, speed, and volume are scalar quantities. 2 The resultant is 22 times greater than each of the equal-length, right-angled vectors. 2 The diagonal represents the resultant vector. 2 (a) Yes. (b) Yes. Answers to Chapter 3 Multiple-Choice Questions 1d, 2b, 3a, 4c, 5d Answers to Chapter 3 Integrated Science Concepts Biology: Gliding 1 Gliding describes a mode of locomotion in which animals move through the air in a controlled fall. 2 The more air resistance an animal encounters, the slower and more controllable its fall. And, the amount of air resistance a falling object encounters depends on the object’s surface area. 3 “ Flying" squirrels have large ï¬, aps of skin between their front and hind legs; Draco lizards have long extendable ribs that support large gliding membranes; “ ï¬, ying" frogs have very long toes with extensive webbing between them; gliding geckos have skin ï¬, aps along their sides and tails in addition to webbed toes. Biology: Animal Locomotion 1 In animal locomotion, an animal typically pushes against some medium (the ground, water, or air) that pushes back on it, providing the force needed for the animal to accelerate. 2 Newton’s third law: the squid pushes the water, the water pushes the squid. 3 The force of friction between your back foot and the ï¬, oor pushes you forward. 4 The slippery surface cannot provide a large reaction force to the duck’s push against it. Answers to Chapter 3 Exercises 1. In the orbiting space shuttle, you are handed two identical closed boxes, one ï¬�lled with sand and the other ï¬�lled with feathers. How can you tell which is which without opening the boxes? Poke or kick the boxes. The one that more greatly resists a change in motion is the one with the greater mass–the one ï¬�lled with sand. 2. Your empty hand is not hurt when it bangs lightly against a wall. Why is it hurt if it is carrying a heavy load? Which of Newton's laws is most applicable here? Mainly the ï¬�rst law, for the bag in motion tends to continue in motion, which results in a squashed hand. 3. Each of the chain of bones forming your spine is separated from its neighbors by disks of elastic tissue. What happens, then, when you jump heavily on your feet from an elevated position? Can you think of a reason why you are a little taller in the morning than in the night? (Hint: Think about how Newton's ï¬�rst law of motion applies in this case.) Newton's ï¬�rst law again–when you jump, you tighten the disks. This is similar to how you can tighten a hammerhead by banging it against a surface. The greater inertia of the massive hammerhead makes it harder to stop than the less massive hammer handle. Similarly, when you jump you tighten your verte-brae. This effect also explains why you're shorter at the end of the day. At night, while lying prone, relaxation undoes the compression and you're taller! 4. As you stand on a ï¬, oor, does the ï¬, oor exert an upward force against your feet? How much force does it exert? Why are you not moved upward by this force? Yes, an upward support force acts on you while standing on a ï¬, oor, which is equal and opposite to the force of gravity on you–your weight. You are not moved upward by this force, because it is only one of two vertical forces acting on you, making the net force zero. 5. To pull a wagon across a lawn with constant velocity, you have to exert a steady force. Reconcile thisfact with Newton's ï¬�rst law, which says that motion with constant velocity indicates no force. You exert a force to overcome the force of friction. This makes the net force zero, which is why the wagon moves without acceleration. If you pull harder, then net force will be greater than zero, and acceleration will occur. 6. A rocket becomes progressively easier to accelerate as it travels through space. Why is this so? (Hint: About 90% of the mass of a newly launched rocket is fuel.) Let Newton's second law guide the answer to this: a F/m. As m gets less (much the mass of the fuel), acceleration a increases for a constant force. 7. As you are leaping upward from the ground, how does the force that you exert on the ground compare with your weight? The force that you exert on the ground is greater than your weight, for you momentarily accelerate upward. Then the ground simultaneously pushes upward on you with the same amount of force. 8. A common saying goes, " It's not the fall that hurts you; it's the sudden stop. " Translate this intoNewton's laws of motion. The sudden stop involves a large acceleration. So in accord with a F/m, a large a means a large F. Ouch! 9. On which of these hills does the ball roll down with increasing speed and decreasing acceleration along the path? (Use this example if you wish to explain to someone the difference between speed and acceleration.) Only on hill B does the acceleration along the path decrease with time, for the hill becomes less steep as motion progresses. When the hill levels off, acceleration will be zero. On hill A, acceleration is constant. On hill C, acceleration increases as the hill becomes steeper. In all three cases, speed increases. 2 10. Neglecting air resistance, if you drop an object, its acceleration toward the ground is 10 m/s . If you 2 throw it down instead, would its acceleration after throwing be greater than 10 m/s ? Why or why not? When air resistance affects motion, the ball thrown upward returns to its starting level with less speed than its initial speed, and also less speed than the ball tossed downward. The downward thrown ball hits the ground below with a greater speed. 11. In the preceding exercise, can you think of a reason why the acceleration of the object thrown 2 downward through the air would actually be less than 10 m/s ? Air resistance on the thrown object decreases the net force on it (mg R), making its acceleration less than that of free fall. 12. You hold an apple over your head. (a) Identify all the forces acting on the apple and their reaction forces. (b) When you drop the apple, identify all the forces acting on it as it falls and the corresponding reaction forces. (a) Two force pairs act; Earth's pull on the apple (action), and the apple's pull on the Earth (reaction). Hand pushes apple upward (action), and apple pushes hand downward (reaction). (b) If air drag can be neglected, one force pair acts; Earth's pull on apple, and apple's pull on Earth. If air drag counts, then air pushes upward on apple (action), and apple pushes downward on air (reaction). 13. Does a stick of dynamite contain force? Defend your answer. Neither a stick of dynamite nor anything else " contains" force. We will see later that a stick of dynamite contains energy, which is capable of producing forces when an interaction of some kind occurs. 14. Can a dog wag its tail without the tail, in turn, " wagging the dog"? (Consider a dog with a relatively massive tail.) No, for in action—reaction fashion, the tail also wags the dog. How much depends on the relative masses of the dog and its tail. 15. If the Earth exerts a gravitational force of 1000 N on an orbiting communications satellite, how much force does the satellite exert on the Earth? 1000 N. 16. If you exert a horizontal force of 200 N to slide a crate across a factory ï¬, oor at constant velocity, how much friction is exerted by the ï¬, oor on the crate? Is the force of friction equal and oppositely directed to your 200-N push? Does the force of friction make up the reaction force to your push? Why not? The friction on the crate is 200 N, which cancels your 200-N push on the crate to yield the zero net force that accounts for the constant velocity (zero acceleration). Although the friction force is equal and oppositely directed to the applied force, the two do not make an action—reaction pair of forces. That's because both forces do act on the same object–the crate. The reaction to your push on the crate is the crate's push back on you. The reaction to the frictional force of the ï¬, oor on the crate is the opposite friction force of the crate on the ï¬, oor. 17. If a Mack truck and motorcycle have a head-on collision, upon which vehicle is the impact force greater? Which vehicle undergoes the greater change in its motion? Explain your answers. In accord with Newton's third law, the force on each will be of the same magnitude. But the effect of the force (acceleration) will be different for each because of the different mass. The more massive truck undergoes less change in motion than the motorcycle. 18. Two people of equal mass attempt a tug-of-war with a 12-m rope while standing on frictionless ice. When they pull on the rope, they each slide toward each other. How do their accelerations compare, and how far does each person slide before they meet? The forces on each are the same in magnitude, and their masses are the same, so their accelerations will be the same. They will slide equal distances of 6 meters to meet at the midpoint. 19. Suppose in the preceding exercise that one person has twice the mass of the other. How far does each person slide before they meet? The person with twice the mass slides half as far as the twice-as-massive person. That means the lighter one slides 4 feet, and the heavier one slides 8 feet (for a total of 12 feet). 20. Which team wins in a tug-of-war; the team that pulls harder on the rope, or the team that pushes harder against the ground? Explain. The winning team pushes harder against the ground. The ground then pushes harder on them, producing a net force in their favor. 21. The photo shows Steve Hewitt and his daughter Gretchen touching. Is Steve touching Gretchen, or is Gretchen touching Steve? Explain. In accord with Newton’s third law, Steve and Gretchen are touching each other. One may initiate the touch, but the physical interaction can’t occur without contact between both Steve and Gretchen. Indeed, you cannot touch without being touched! 22. When your hand turns the handle of a faucet, water comes out. Does your push on the handle and the water coming out comprise an action—reaction pair? Defend your answer. No. The reaction to the force of your hand on the handle is the force of the handle on your hand. A on B, action; B on A, reaction (not C on A!). 23. Why is it that a cat that falls from the top of a 50-story building will hit the ground no faster than if it fell from the 20th story? The terminal speed attained by the falling cat is the same whether it falls from 50 stories or 20 stories. Once terminal speed is reached, falling extra distance does not affect the speed. (The low terminal velocities of small creatures enable them to fall without harm from heights that would kill larger creatures.) 24. Free fall is motion in which gravity is the only force acting. (a) Is a sky diver who has reached terminal speed in free fall? (b) Is a satellite circling the Earth above the atmosphere in free fall? (a) A skydiver encountering no air resistance is in free fall. One at terminal velocity does encounter air resistance and is not in free fall. (b) The only force acting on a satellite is that due to gravity, so a satellite is in free fall (much more about this in Chapter 5). 25. How does the weight of a falling body compare to the air resistance it encounters just before it reaches terminal velocity? After? Before reaching terminal velocity, weight is greater than air resistance. After reaching terminal velocity, both weight and air resistance are of the same magnitude. Then the net force and acceleration are both zero. 26. You tell your friend that the acceleration of a skydiver decreases as falling progresses. Your friend then asks if this means the skydiver is slowing down. What is your response? Your friend is correct; the skydiver is, in fact, slowing down as acceleration decreases in a dive. Eventually the acceleration will become zero, in which case the diver has reached terminal velocity. 27. If and when Galileo dropped two balls from the top of the Leaning Tower of Pisa, air resistance was not really negligible. Assuming both balls were the same size yet one much heavier than the other, which ball struck the ground ï¬�rst? Why? Air resistance is not really negligible for so high a drop, so the heavier ball does strike the ground ï¬�rst. But although a twice-as-heavy ball strikes ï¬�rst, it falls only a little faster, and not twice as fast, which is what followers of Aristotle believed. Galileo recognized that the small difference is due to friction and would not be present if there were no friction. 28. If you simultaneously drop a pair of tennis balls from the top of a building, they will strike the ground at the same time. If one of the tennis balls is ï¬�lled with lead pellets, will it fall faster and hit the ground ï¬�rst? Which of the two will encounter more air resistance? Defend your answers. The heavier tennis ball will strike the ground ï¬�rst for the same reason the heavier parachutist in Figure 3. 10 strikes the ground ï¬�rst. Note that although the air resistance on the heavier ball is smaller relative to the weight of the ball, it is actually greater than the air resistance that acts on the other ball. Why? Because the heavier ball falls faster, and air resistance is greater for greater speed. 29. Which is more likely to break, the ropes supporting a hammock stretched tightly between a pair of trees or one that sags more when you sit on it? Defend your answer. A hammock stretched tightly has more tension in the supporting ropes than one that sags. The tightly stretched ropes are more likely to break. 30. A stone is shown at rest on the ground. (a) The vector shows the weight of the stone. Complete the vector diagram showing another vector that results in zero net force on the stone. (b) What is the conventional name of the vector you have drawn? (a) The other vector is upward as shown. (b) It is called the normal force. 31. Here a stone is suspended at rest by a string. (a) Draw force vectors for all the forces that act on the stone. (b) Should your vectors have a zero resultant? (c) Why, or why not? (a) As shown. (b) Yes. (c) Because the stone is in equilibrium. 32. Here the same stone is being accelerated vertically upward. (a) Draw force vectors to some suitable scale showing relative forces acting on the stone. (b) Which is the longer vector, and why? (a) As shown. (b) Upward tension force is greater to result in upward net force. 33. Suppose the string in the preceding exercise breaks, and the stone slows in its upward motion. Draw a force vector diagram of the stone when it reaches the top of its path. It would be the same except that the upward vector would be absent. Only the downward mg vector acts. 34. What is the net force on the stone in the preceding exercise at the top of its path? Its instantaneous velocity? Its acceleration? The acceleration of the stone at the top of its path, or anywhere where the net force on the stone is mg, is g. 35.

Here is the stone sliding down a friction-free incline. (a) Identify the forces that act on it and draw appropriate force vectors. (b) By the parallelogram rule, construct the resultant force on the stone (carefully showing it has a direction parallel to the incline–the same direction as the stone's acceleration). (a) Weight and normal force only. (b) As shown. 36. Here is the stone at rest, interacting with both the surface of the incline and the block. (a) Identify all the forces that act on the stone, and draw appropriate force vectors. (b) Show that the net force on the stone is zero. (Hint 1: There are two normal forces on the stone. Hint 2: Be sure the vectors you draw are for forces that act on the stone, not by the stone on the surfaces.) (a) As shown. (b) Note the resultant of the normals is equal and opposite to the stone's weight. Solutions to Chapter 3 Problems 1. A 400-kg bear grasping a vertical tree slides down at constant velocity. Show that the friction that acts on the bear is about 4000 N. Constant velocity means zero acceleration and, therefore, zero net force. So the friction force must be equal to the bear's weight, mg. 2. When two horizontal forces are exerted on a cart, 600 N forward and 400 N backward, the cart undergoes acceleration. Show that the additional force needed to produce nonaccelerated motion is 200 N. The given pair of forces produce a net force of 200 N forward, which accelerates the cart. To make the net force zero, a force of 200 N backward must be exerted on the cart. 3. You push with 20-N horizontal force on a 2-kg mass on a horizontal surface against a horizontal 2 friction force of 12 N. Show that the acceleration is 4 m/s . 2 Acceleration a Fnet/m (20 N 12 N)/2 kg 8 N/2 kg 4 m/s . 4. You push with 40-N horizontal force on a 4-kg mass on a horizontal surface. The horizontal friction 2 force is 12 N. Show that the acceleration is 7 m/s . 2 Acceleration a Fnet/m (40 N 24 N)/4 kg 16 N/4 kg 4 m/s . 2 5. A cart of mass 1 kg is accelerated 1 m/s by a force of 1 N. Show that a 2-kg cart pushed with a 2-N 2 force would also accelerate at 1 m/s . 2 Acceleration a Fnet/m 2 N/2 kg 1 m/s , the same. 2 6. A rocket of mass 100, 000 kg undergoes an acceleration of 2 m/s . Show that the force developed by the rocket engines is 200, 000 N. 2 F ma (100, 000 kg)(2 m/s) 200, 000 N. 7. A 747 jumbo jet of mass 30, 000 kg experiences a 30, 000-N thrust for each of its engines during take2 off. Show that its acceleration is 4 m/s . 2 Acceleration a Fnet/m (4 30, 000 N)/30, 000 kg 4 m/s . 8. Suppose the jumbo jet in the previous problem ï¬, ies against an air resistance of 90, 000 N while the thrust of all four engines is 100, 000 N. Show that its acceleration will be about 0. 3 m/s2. What will the acceleration be when air resistance builds up to 100, 00 N? air resistance 90, 000 N thrust 100, 000 N a = = 2 = 0. 33 m/s Fnet 100, 000 N -90, 000 N 10, 000 N m 30, 000 kg 30, 000 kg When air resistance equals 100, 000 N it will equal the forward thrust force. The net force will be zero, as will acceleration. 9. A boxer punches a sheet of paper in midair, bringing it from rest to a speed of 25 m/s in 0. 05 second. If the mass of the paper is 0. 003 kg, show that the force the boxer exerts on it is only 1. 5 N. F ma m v/t 0. 003 kg [(25 m/s)/0. 05 s] 1. 5 N. 10. Suppose that you are standing on a skateboard near a wall and that you push on the wall with a force of 30 N. (a) How hard does the wall push on you? (b) Show that if your mass is 60 kg your acceleration 2 while pushing will be 0. 5 m/s . 2 The wall pushes as much on you, 30 N. Acceleration a Fnet/m 30 N/60 kg 0. 5 m/s . 11. If raindrops fall vertically at a speed of 3 m/s and you are running horizontally at 4 m/s, show that the drops will hit your face at a speed of 5 m/s. By the Pythagorean theorem, V 2[(3m/s) (4 m/s)] 5 m/s. 12. Horizontal forces of 3 N and 4 N act at right angles on a block of mass 5 kg. Show that the resulting 2 acceleration will be 1 m/s . Acceleration a Fnet/m 2[(3. 0 N) (4. 0 N)]/5 kg 1. 0 m/s . 13. Suzie Skydiver with her parachute has a mass of 50 kg. (a) Before opening her chute, show that the force of air resistance she encounters when reaching terminal velocity is about 500 N. (b) After her chute is open and she again reaches a smaller terminal velocity, show that the force of air resistance she encounters is also about 500 N. (c) Discuss why your answers are the same. (a) Force of air resistance will be equal to her weight, mg, or 500 N. (b) She'll reach the same air resistance, but at a slower speed, 500 N. (c) The answers are the same, but for different speeds. In each case, she attains equilibrium (no acceleration). 2 2 2 2 2 14. An airplane with an air speed of 120 km/h encounters a 90-km/h crosswind. Show that its groundspeed is 150 km/h. By the Pythagorean theorem, V 2[(120 m/s) + (90 m/s)] 150 m/s. 2 2 Chapter 4: Momentum and Energy Answers to Chapter 4 Review Questions 1 Moving skateboard; anything at rest has no momentum. 2 Enormous momentum due to huge mass. 3 Force is a push or pull, while impulse is the product of force and time. 4 By increasing force, or increasing the time the force is exerted. 5 A cannonball will have more momentum coming from the long cannon due to the force acting over a longer time. 6 (3) (Twice the change occurs if speed thrown is the same as speed caught.) 7 (3) (Twice if speed thrown is the same as speed caught.) 8 No because, although you produce impulse on the car, the car produces an equal and opposite impulse on you, so the sum of the impulses equals zero net impulse. 9 That it remains unchanged in a process.

10 An elastic collision is a collision in which colliding objects rebound without lasting deformation or the generation of heat; an inelastic collision is a collision in which the colliding objects become distorted, generate heat, and possibly stick together. Momentum is conserved during elastic collisions. 11 Has the same initial speed of A. 12 Half speed. 13 When it undergoes a change–as when being transferred or transformed. 14 Work, which changes energy. 15 Joules. True. 16 17 Four watts. 18 Twice. 19 Twice. 20 Four times as much. 21 Whether or not it experiences a change in energy. 16 times as much work to stop the car. 1 2 With no external work input or output, the energy of a system doesn’t change. Energy cannot be created or destroyed. 3 The source of energy is sunlight that evaporated water from the ocean, which ended up as rain in mountains and trapped behind dams. 4 Yes. Yes. No! (There is no way to increase energy without doing work.) 5 Twice the force through half the distance. 6 No way! If that is done, new physics is afoot! Such would violate the conservation of energy. Answers to Chapter 4 Multiple-Choice Questions 1c, 2c, 3a, 4b, 5a Answers to Chapter 4 Integrated Science Concepts Biology: The Impulse—Momentum Relationship in Sports 1 (a) An extended hand has room to move backward when the ball is caught. This stretches the time, resulting in less force. (b) The force of impact will be less if momentum changes over a long time. Bymaking t long, F will be smaller. (c) The shorter time is accompanied by a greater force when themomentum of the arm is reduced. 2 In accord with Newton’s third law, the forces are equal. Only the resilience of the human hand and the training she has undergone to toughen her hand allow her to perform this without breaking any bones. 3 The impulse will be greater if her hand bounces from

the bricks. If the time of contact is not increased, a greater force is then exerted on the bricks (and on her hand). Biology and Chemistry: Glucose–Energy for Life 1 The “ burning" that goes on in cells differs from the burning or combustion of a log on a campï¬�re in that the cellular process is much slower and more controlled. 2 You are powered by solar energy in the sense that the energy you use to perform the biochemical andphysical processes needed to sustain life comes from your food which stores chemical energy. Thischemical energy is solar energy that has been transformed by photosynthesizing organisms. Answers to Chapter 4 Exercises 1. What is the purpose of a “ crumple zone" (which has been manufactured to collapse steadily in a crash) in the front section of an automobile? A steady collapse in a crash extends the time that the seat belt and air bags slow the passengers less violently. 2. To bring a supertanker to a stop, its engines are typically cut off about 25 kg from port. Why is it so difiï¬�cult to stop or turn a supertanker? Supertankers are so massive, that even at modest speeds, their motional inertia, or momenta, are enormous. This means enormous impulses are needed for changing motion. How can large impulses be produced with modest forces? By applying modest forces over long periods of time. Hence, the force of the water resistance over the time it takes to coast 25 kilometers sufiï¬�ciently reduces the momentum. 3. Why might a wine glass survive a fall onto a carpeted ï¬, oor but not onto a concrete ï¬, oor? The time during which momentum decreases is lengthened, thereby decreasing the force that brings the wine glass to rest. Less force means less chance of breaking. 4. If you throw an egg against a wall, the egg will break. If you throw an egg at the same speed into a sagging sheet, it won’t break.

Why? When the moving egg makes contact with a sagging sheet, the time it takes to stop it is extended. More time means less force, and a less-likely broken egg. 5. Why is a punch more forceful with a bare ï¬�st than with a boxing glove? Impact with a boxing glove extends the time during which momentum of the ï¬�st is reduced and lessens the force. A punch with a bare ï¬�st involves less time and, therefore, more force. 6. A boxer can punch a heavy bag for more than an hour without tiring but will tire quickly when boxing with an opponent for a few minutes. Why? (Hint: When the boxer's punches are aimed at the bag, what supplies the impulse to stop them? When aimed at the opponent, what (or who) supplies the impulse to stop the punches that are missed?) When a boxer hits his or her opponent, the opponent contributes to the impulse that changes the momentum of the punch. When punches miss, no impulse is supplied by the opponent–all effort that goes into reducing the momentum of the punches is supplied by the boxer. This tires the boxer. This is very evident to a boxer who can punch a heavy bag in the gym for hours and not tire, but who ï¬�nds by contrast that a few minutes in the ring with an opponent is a tiring experience. 7. Railroad cars are loosely coupled so that there is a noticeable time delay from the time the ï¬�rst car is moved and the time the last cars are moved from rest by the locomotive. Discuss the advisability of this loose coupling and slack between cars from an impulse—momentum point of view. Without this slack, a locomotive might simply sit still and spin its wheels. The loose coupling enables a longer time for the entire train to gain momentum, requiring less force of the locomotive wheels against the track. In this way, the overall required impulse is broken into a series of smaller impulses. (This loose coupling can be very important for braking as well.) 8. A fully dressed person is at rest in the middle of a pond on perfectly frictionless ice and must reach the shore. How can this be accomplished? To get to shore, the person may throw keys or coins or an item of clothing. The momentum of what is thrown will be accompanied by the thrower’s oppositely directed momentum. In this way, one can recoil toward shore. (One can also inhale facing the shore and exhale facing away from the shore.) 9. A high-speed bus and an innocent bug have a head-on collision. The sudden change in momentum of the bus is greater, less, or the same as the change in momentum of the unfortunate bug? The momentum of both bug and bus change by the same amount, because the amount of force and the time and, therefore, the amount of impulse, are the same on each. Momentum is conserved. Speed is another story. Because of the huge mass of the bus, its reduction of speed is very tiny–too small for the passengers to notice. 10. Why is it difï¬�cult for a ï¬�reï¬�ghter to hold a hose that ejects large quantities of water at a high speed? The large momentum of the spurting water is met by a recoil that makes the hose difï¬�cult to hold, just as a shotgun is difï¬�cult to hold when it ï¬�res birdshot. 11. You’re on a small raft next to a dock and jump from the raft only to fall into the water. What physics principle did you fail to take into account? Oops, the conservation of momentum was overlooked. Your momentum forward equals (approximately) the momentum of the recoiling raft. 12. Your friend says the conservation of momentum is violated when you step off a chair and gain momentum as you fall. What do you say? Whether or not momentum is conserved depends on the system. If the system in question is you as you fall, then there is an external force acting on you (gravity), and momentum increases and is, therefore, not conserved. But if you enlarge the system to be you and the Earth that pulls you, then momentum is conserved, for the force of gravity on you is internal to the system. Your momentum of fall is balanced by the equal but opposite momentum of the Earth coming up to meet you! 13. If a Mack truck and a Honda Civic have a head-on collision, which vehicle will experience the greater force of impact? The greater impulse? The greater change in its momentum? The greater acceleration? The magnitude of force, impulse, and change in momentum will be the same for each. The Civic undergoes the greater acceleration, because its mass is less. 14. Would a head-on collision between two cars be more damaging to the occupants if the cars stuck together or if the cars rebounded upon impact? Cars brought to a rapid halt experience a change in momentum and a corresponding impulse. But greater momentum change occurs if the cars bounce, with correspondingly greater impulse and, therefore, greater damage. Less damage results if the cars stick upon impact than if they bounce apart. 15. In Chapter 3, rocket propulsion was explained in terms of Newton’s third law. That is, the force that propels a rocket is from the exhaust gases pushing against the rocket, the reaction to the force the rocket exerts on the exhaust gases. Explain rocket propulsion in terms of momentum conservation. If the rocket and its exhaust gases are treated as a single system, the forces between rocket and exhaust gases are internal, and momentum in the rocket—gases system is conserved. Any momentum given to the gases is equal and opposite to momentum given to the rocket. A rocket attains momentum by giving momentum to the exhaust gases. 16.

Suppose there are three astronauts outside a spaceship, and two of them decide to play catch with the third man. All the astronauts weigh the same on Earth and are equally strong. The ï¬�rst astronaut throws the second one toward the third one and the game begins. Describe the motion of the astronauts as the game proceeds. In terms of the number of throws, how long will the game last? We assume the equal strengths of the astronauts means that each throws with the same speed. Because the masses are equal, when the ï¬�rst throws the second, both the ï¬�rst and second move away from each other at equal speeds. Say the astronaut moves to the right with velocity V, and the ï¬�rst recoils with velocity V. When the third makes the catch, both she and the second move to the right at velocity V/2 (twice the mass moving at half the speed, like the freight cars in Figure 4. 11). When the third makes her throw, she recoils at velocity V (the same speed she imparts to the thrown astronaut) which is added to the V/2 she acquired in the catch. So, her velocity is V V/2 3V/2, to the right–too fast to stay in the game. Why? Because the velocity of the second astronaut is V/2 V V/2, to the left–too slow to catch up with the ï¬�rst astronaut who is still moving at V. The game is over. Both the ï¬�rst and the third got to throw to the second astronaut only once! 17. How is it possible that a ï¬, ock of birds in ï¬, ight can have a momentum of zero, but not have zero kinetic energy? They may ï¬, y in opposite directions wherein the momenta cancel to zero. But if moving, there is no way kinetic energy can cancel. Hence, the difference between a vector quantity (momentum) and a scalar quantity (kinetic energy). 18. When a cannon with a long barrel is ï¬�red, the force of expanding gases acts on the cannonball for a longer distance. What effect does this have on the velocity of the emerging cannonball? When a cannon with a long barrel is ï¬�red, more work is done as the cannonball is pushed through the longer distance. A greater KE is the result of the greater work, so of course, the cannonball emerges with a greater velocity. (It might be mentioned that the force acting on the bullet is not constant but decreases with increasing distance inside the barrel.) 19. You and a ï¬, ight attendant toss a ball back and forth in an airplane in ï¬, ight. Does the KE of the ball depend on the speed of the airplane? Carefully explain. The KE of the tossed ball relative to occupants in the airplane does not depend on the speed of the airplane. The KE of the ball relative to observers on the ground below, however, is a different matter. KE, like velocity, is relative. 20. Can something have energy without having momentum? Explain. Can something have momentum without having energy? Defend your answer. If an object has KE, then it must have momentum–for it is moving. But it can have potential energy with-out being in motion and, therefore, without having momentum. And every object 2 has “ energy of being"– stated in the celebrated equation E mc . Whether an object moves or not, it has some form of energy. If it has KE, then with respect to the frame of reference in which its KE is measured, it also has momentum. 21. To combat wasteful habits, we often urge others to “ conserve energy" by turning off lights when they are not in use, for example, or by setting thermostats at a moderate level. In this chapter, we also speak of “ energy conservation. " Distinguish between these two usages. In the physical science sense, energy cannot be created or destroyed. When consuming energy, however, we can use more than we need and be wasteful. So we speak of saving energy, using it more wisely, and not in the science sense of conserving it. 22. An inefï¬�cient machine is said to “ waste energy. " Does this mean that energy is actually lost? Explain. Energy is dissipated into nonuseful forms in an inefï¬�cient machine and is “ lost" only in the loose sense of the word. In the strict sense, it can be accounted for and is therefore not lost. 23. A child can throw a baseball at 20 mph. Some professional ball players can throw a baseball 100 mph, ï¬�ve times as fast. How much more energy does the pro ball player give to the faster ball? Twenty-ï¬�ve times as much energy (as speed is squared for kinetic energy). 24. If a golf ball and a Ping-Pong ball both move with the same kinetic energy, can you say which has the greater speed? Explain in terms of KE. Similarly, in a gaseous mixture of massive molecules and light molecules with the same average KE, can you say which have the greater speed? If KEs are the same but masses differ, then the ball with smaller mass has the greater speed. 2 2 That is, 1/2 Mv 1/2 mV , and likewise with molecules, where lighter ones move faster on the average than more massive ones. (We will see in Chapter 6 that temperature is a measure of average molecular KE–lighter molecules in a gas move faster than same-temperature heavier molecules.) 25. Consider a pendulum swinging to and fro. At what point in its motion is the KE of the pendulum bob at a maximum? At what point is its PE at a maximum? When its KE is half its maximum value, how much PE does it have? The KE of a pendulum bob is maximum where it moves fastest, at the lowest point; PE is maximum at the uppermost points. When the pendulum bob swings by the point that marks half its maximum height, it has half its maximum KE, and its PE is halfway between its minimum and maximum values. If we deï¬�ne PE 0 at the bottom of the swing, the place where KE is half its maximum value is also the place where PE is half its maximum value, and KE PE at this point. (In accordance with energy conservation: total energy KE PE.) 26. A physics instructor demonstrates energy conservation by releasing a heavy pendulum bob, as shown in the sketch, allowing it to swing to and fro. What would happen if in his exuberance he gave the bob a slight shove as it left his nose? Why? If the ball is given an initial KE, it will return to its starting position with that KE (moving in the other direction!) and hit the instructor. (The usual classroom procedure is to release the ball from the nose at rest. Then when it returns it will have no KE and will stop short of bumping the nose.) 27. Discuss the design of the roller coaster shown in the sketch in terms of the conservation of energy. The design is impractical. Note that the summit of each hill on the roller coaster is the same height, so the PE of the car at the top of each hill would be the same. If no energy were spent in overcoming friction, the car would get to the second summit with as much energy as it starts with. But in practice, there is considerable friction, and the car would not roll to its initial height and have the same energy. So the maximum height of succeeding summits should be lower to compensate for friction. 28. Consider the identical balls released from rest on Tracks A and B as shown. When each ball has reached the right end of its track, which will have the greater speed? Why is this question easier to answer than the similar question asked in Exercise 25 back in Chapter 2? Both will have the same speed, because both have the same PE at the ends of the track and, therefore, the same KEs. This is a relatively easy question to answer because speed is asked for, whereas the similar question in Chapter 2 asked for which ball got to the end sooner.

The question asked for time–which meant ï¬�rst establishing which ball had the greater average speed. 29. Strictly speaking, does a car burn more gasoline when the lights are turned on? Does the overall consumption of gasoline depend on whether or not the engine is running? Defend your answer. Yes, a car burns more gasoline when its lights are on. The overall consumption of gasoline does not depend on whether or not the engine is running. Lights and other devices run off the battery, which " run down" the battery. The energy used to recharge the battery ultimately comes from the gasoline. 30. If an automobile had an engine that was 100% efï¬�cient, would it be warm to your touch? Would its exhaust heat the surrounding air? Would it make any noise? Would it vibrate? Would any of its fuel go unused? An engine that is 100% efï¬�cient would not be warm to the touch, its exhaust would not heat the air, and it would not make any noise or vibrate. This is because all these are transfers of energy, which cannot happen if all the energy given to the engine is transformed to useful work. Solutions to Chapter 4 Problems 1. A car with a mass of 1000 kg moves at 20 m/s. Show that the braking force needed to bring the car to a halt in 10 s is 2000 N. From Ft mv, F mv/t (1000 kg)(20 m/s)/10 s 2000 N.[Can you see this could also be solved by Newton's second law: F ma (1000 kg)(20 m/s/10 s) 2000 N.] 2. A railroad diesel engine weighs four times as much as a freight car. If the diesel engine coasts at 5 km per hour into a freight car that is initially at rest, show that the two coast at 4 km/h after they couple together. The answer is 4 km/h. Let m be the mass of the freight car, 4m the mass of the diesel engine, and v the speed after both have coupled together. Before collision, the total momentum is due only to the diesel engine, 4m(5 km/h), because the momentum of the freight car is 0. After collision, the combined mass is (4m m), and combined momentum is (4m m)v. By the conservation of momentum equation: momentumbefore momentumafter 4m(5 km/h) 0 (4m # m)v (20m km/h) v 4 km/h 5m(Note that you don’t have to know m to solve the problem.) 3. A 5-kg ï¬�sh swimming at 1 m/s swallows an absent-minded 1-kg ï¬�sh at rest. (a) Show that the speed ofthe larger ï¬�sh after lunch is 5 m/s. (b)What would be its speed if the smaller ï¬�sh were swimmingtoward it at 4 m/s? (a) Momentum before lunch momentum after lunch(5 kg)(1 m/s) 0 (5 kg 1 kg)v5 kg m/s (6 kg) vv 5/6 m/s. (b) Momentum before lunch momentum after lunch(5 kg)(1 m/s) 1 kg (4 m/s) (5 kg 1 kg)3v5 kg m/s 4 kg m/s (6 kg)vv 1/6 m/s 4. Comic-strip hero Superman meets an asteroid in outer space and hurls it at 800 m/s, as fast as a bullet. The asteroid is a thousand times more massive than Superman. In the strip, Superman is seen at rest after the throw. Taking physics into account, what would be his recoil velocity? By momentum conservation, asteroid mass 800 m/s Superman’s mass v. Because the asteroid’s mass is 1000 times Superman’s,(1000m)(800 m/s) mvv 800, 000 m/s. This is nearly 2 million miles per hour! 5. Consider the inelastic collision between the two freight cars in Figure 4. 11. The momentum before and after the collision is the same. The KE, however, is less after the collision than before the collision. How much less, and what has become of this energy? The freight cars have only half the KE possessed by the single car before collision. Here’s how to ï¬�gure it: . 2 KEbefore 1/2 mv 2 2 2 KEafter 1/2 (2m)(v/2) 1/2 (2m)v /4 1/4 mv . What becomes of this energy? Most of it goes into nature’s graveyard– thermal energy. 6. This question is typical on some driver’s license exams: A car moving at 50 km/h skids 15 m with locked brakes. How far will the car skid with locked brakes at 150 km/h? 2 At three times the speed, it has nine times (3) the KE and will skid nine times as far–135 m. Because the frictional force is about the same in both cases, the distance has to be nine times as great for nine times as much work done by the pavement on the car. 7. In the hydraulic machine shown, it is observed that, when the piston is pushed down 10 cm, the large piston is raised 1 cm. If the small piston is pushed down with a force of 100 N, show that the large piston is capable of exerting 1000 N of force. (Fd)input (Fd)output (100 N 10 cm)input (? 1 cm)output So we see that the output force is 1000 N (or less