11. An elastic ball that wastes 30% of the collision energy as heat when it bounces on a hard floor will rebound to 70% of the height from which it was dropped. Explain the 30% loss in height.

   E.11 A 30% loss of rebound height is a 30% loss of gravitational potential energy—equal to the energy that became thermal energy.

12. The best running tracks have firm but elastic rubber surfaces. How does a lively surface assist a runner?

   E.12 An elastic track stores energy as it dents when the runner’s foot presses against it and then returns that energy to the runner as it undents.

13. Why is it so exhausting to run on soft sand?

   E.13 You do work on the sand as you step on it, but the sand doesn’t return this energy to you as you lift your foot back up again.

14. Steep mountain roads often have emergency ramps for trucks with failed brakes. Why are these ramps most effective when they are covered with deep, soft sand?

   E.14 Sand dents easily as the truck plows through it and extracts energy from the truck. The truck does work in pushing the sand out of the way. The sand converts that work into safe thermal energy.

15. There have been baseball seasons in which so many home runs were hit that people began to suspect that something was wrong with the baseballs. What change in the baseballs would account for them traveling farther than normal?

   E.15 An increase in the balls’ coefficients of restitution.

16. During rehabilitation after hand surgery, patients are often asked to squeeze and knead putty to strengthen their muscles. How does the energy transfer in squeezing putty differ from that in squeezing a rubber ball?

   E.16 Energy transferred while deforming putty is converted into thermal energy and never returns to the person's hand. However, energy transferred while deforming a rubber ball becomes elastic potential energy in the ball and returns to the person's hand when the rubber ball returns to its spherical shape.

17. Your car is on a crowded highway with everyone heading south at about 100 km/h (62 mph). The car ahead of you slows down slightly and your car bumps into it gently. Why is the impact so gentle?

   E.17 Your relative velocity is small—in your frame of reference the car in front of you is barely moving, so the impact is very gentle.

18. Bumper cars are an amusement park ride in which people drive small electric vehicles around a rink and intentionally bump them into one another. All of the cars travel at about the same speed. Why are head-on collisions more jarring than other types of collisions?

   E.18 During a head-on collision, the relative velocity is enormous—the sum of the two individual velocities—and the forces, accelerations, and momentum transfers are enormous as well.

19. When two trains are traveling side by side at breakneck speed, it’s still possible for people to jump from one train to the other. Explain why this can be done safely.

   E.19 Because the trains’ relative velocity is zero, a person jumping between them views them both as essentially stationary.

20. If you drop a steel marble on a wooden floor, why does the floor receive most of the collision energy and contribute most of the rebound energy?

   E.20 The marble is stiffer than the floor, so the floor dents more than the marble. Since the forces are equal in magnitude, the floor also has the most work done on it during the collision and is thus responsible for most of the rebound energy.

21. A RIF (reduced injury factor) baseball has the same coefficient of restitution as a normal baseball except that it deforms more severely during a collision. Why does this increased deformability lessen the forces exerted by the ball during a bounce and reduce the chances of its causing injury?

   E.21 During a bounce, the work done on a RIF ball—to store energy in it—involves a smaller force exerted for a longer distance.

22. Padded soles in running shoes soften the blow of hitting the pavement. Why does padding reduce the forces involved in bringing your foot to rest?
E.22 With padding in your shoes, you feet stop over a longer period of time when they encounter the pavement. The momentum transfer or impulse is the same, but the force is smaller while the time is longer.

23. Some athletic shoes have inflatable air pockets inside them. These air pockets act like springs that become stiffer as you pump up the air pressure. High pressure also makes you bounce back up off the floor sooner. Why does high pressure shorten the bounce time?

E.23 At high pressure, the shoes are stiffer and exert larger forces when distorted. They accelerate more rapidly and bounce faster.

Additional questions:

1. Define collision energy and rebound energy.
   a. Collision energy is energy absorbed during a collision. Rebound energy is energy released after a collision.

2. What is the coefficient of restitution?
   a. It is the ratio of rebound speed divided by collision speed.

3. Explain the difference between a “lively” and “dead” surface. Give examples of each.
   a. A lively surface returns most of the collision energy. Concrete is lively while sand or grass is dead.

4. A blue car is traveling at 50 mph and a red car at 20 mph. What is their relative velocity if they are heading toward each other? What is the relative velocity if they are traveling in the same direction?
   a. Toward each other – 70 mph. Same direction – 30 mph.

5. Why do baseball batters try to hit the ball at the bat’s center of percussion?
   a. If they hit the center of percussion, the handle of the bat will not accelerate and therefore will not impose a force on the hands of the batter.

6. Explain the difference between an elastic collision and an inelastic collision?
   a. In an elastic collision, all of the collision energy is returned to the colliding objects. No energy is lost to a disordered form.

7. Why do baseball batters try to hit the ball near a vibrational node of the bat?
   a. It will cause no vibration in the bat.