1. A baseball of mass 0.145 kg sits on a tee. A kid's bat hits the ball and maintains contact for 0.0500 s. The result is that the ball leaves the tee with velocity 15.0 m/s, 0.0º. (a) Find the momentum of the ball as it leaves the tee. (b) Find the net force that acted on the ball. (c) Find the net impulse. (d) Estimate the force of the bat on the ball.

2. A rock that weighs 8.00 N is launched straight up with momentum 30.0 kg m/s, 90.0º and hits a tree branch 1.50 s later. (a) Find the impulse of gravity. (b) Find the rock's momentum at impact.

3. A bullet of mass 7.1 grams and velocity 290 m/s, 0.0º impacts a wooden target and "burrows" into the wood. (a) Find the change in momentum of the bullet. (b) What is the impulse on the wood? (c) Estimate the distance and/or time and use to find the force. (d) Show consistency with work-energy.

4. A ball is dropped and bounces off the floor. Measure the mass, initial height, and rebound height. (a) Determine the speed of the ball just before and just after impact. (b) Find the change in momentum that occurs *during* the bounce. (c) Compare to the impulse measured with a force plate. (d) Determine the average force of impact.

5. A model rocket engine burns propellant at a rate of 6.0 grams/second. The exhaust gases leave the nozzle at a speed of 750 m/s. (a) Find the thrust of the engine. (b) If the total amount of propellant is 13.0 grams, what is the impulse of the engine?

6. The wind in a certain hurricane has velocity of 55 m/s, north. Estimate the force this wind exerts on a wall of dimensions 5.00 m × 10.0 m on the south side of a house. Density of air = 1.29 kg/m^3.

7. The propeller on the fan cart has a radius *r*. Derive an expression modeling the thrust as equivalent to the rate of change in momentum of air passing through the fan. Express result in terms of density of air, ρ, speed of air, *v*, and *r*.

8. A 6.00 kg bowling ball with speed 9.00 m/s strikes a 75<u>0</u> g pin. This slows the ball to 7.00 m/s. Find the speed of the pin due to the impact.

9. Cart A, mass 2.0 kg and velocity 12 m/s, 0°, collides with cart B, mass 7.0 kg at rest. After the collision, cart B has velocity 4.0 m/s,0°. Find the velocity of cart A after the collision.

10. A 5.0 kg cannonball is fired with a muzzle velocity $4\underline{0}$ m/s, 0° from a cannon that has a mass of 160 kg. Determine the recoil velocity of the cannon.

11. Two kids on skateboards roll along together (side by side), traveling at 2.00 m/s. The 60.0 kg kid pulls back on the 50.0 kg kid, which boosts his own speed to 3.00 m/s. (a) Find the resulting speed of the 50.0 kg kid. (b) How much momentum is transferred?

12. A boy and a wagon, with total mass 45.0 kg roll with velocity 1.50 m/s, 0.0°. The boy has with him in the wagon a 0.800 kg brick. With what velocity would he have to throw the brick in order to stop himself and the wagon? Give your answer in two different reference frames: that of the earth and that of the wagon.

13. Two cars collide at an intersection and stick together. The two cars slide together across the wet pavement. Determine the velocity of the two cars sliding together. Initial values: $m_1 = 15\underline{0}0$ kg, $\mathbf{v}_1 =$ 15.0 m/s, north; $m_2 = 18\underline{0}0$ kg, $\mathbf{v}_2 = 20.0$ m/s, west.

14. A pellet (1.00 g, 30.0 m/s) is fired into a bean can (15.0 g), initially at rest on atop a post. For each of the following cases determine the change in kinetic energy of the system: (a) The pellet comes to rest. (b) The pellet sticks in the can. (c) The pellet bounces back off the can at 5.00 m/s. Which of these cases is most elastic? Least elastic?

15. Object A, mass 2.00 kg and initial velocity 7.00 m/s, 0.0°, collides with object B, mass 6.00 kg and initial velocity 4.00 m/s, 180.0°. (a) Determine the greatest amount of kinetic energy that could be "lost" during the collision. (b) Show that if object B rebounds with velocity 1.50 m/s, 0.0° it would be a perfectly elastic collision.

16. Two objects of the same mass undergo a perfectly elastic collision. Object A is initially at rest and object B initially has velocity 10.0 m/s, 0°. Determine the velocity of each object after the collision (assuming one dimensional motion).

17. A lab cart with mass 1.5 kg moves with velocity 6.0 m/s, 0° across a track before colliding elastically with a second cart that has a mass of 0.50 kg. Determine the velocity of each object after the collision.

18. NASA often uses a “gravitational slingshot” to boost the speed of a space probe. In this maneuver, the probe approaches a planet and swings around it because of the gravity, and then moves away from the planet at a higher speed than it had previously. This can be analyzed as an elastic “collision”! Suppose the planet is Earth (mass 5.974×10^{24} kg, orbital speed = 29.8 km/s) and the space probe has mass 950 kg and initial speed 9.6 km/s. Determine the boost in speed assuming the probe reverses its direction in the interaction.