1. Automobile Collisions
   a) In an automobile collision, you are better off being in a more massive car, all other things being equal. Why?
   b) Explain how an airbag in an automobile may help to protect a passenger from serious injury in case of a collision. Hint: think about the situation in terms of the momentum–impulse theorem and the concept of "average force." (Related question: If you had to jump off of a tall building, why would you rather jump into a bin filled with pillows than just hit the concrete?)

2. A gnat runs into the windshield of a moving car. Is the gnat’s change in momentum greater than, less than, or equal to the car’s change in momentum? Explain.

3. When a ball bounces off of a wall with the same speed it started with, its momentum is not conserved. Here’s why: If the momentum before the bounce was $p$, then the momentum after the bounce was $-p$. Thus the momentum of the ball changed. (The change in momentum was $\Delta p = (-p) - (p) = -2p$.) Does this violate the law of conservation of momentum? Why or why not?

4. At what speed do a bicycle and its rider, with a combined mass of 100 kg, have the same momentum as a 1500 kg car traveling at 5.0 m/s? [K2E:9.2]

5. A 10,000 kg railroad car is rolling at 2.0 m/s when a 4000 kg load of gravel is suddenly dropped into it. What is the car’s speed just after the gravel is loaded? [K2E:9.14]

6. Two 500 g blocks of wood are 2.0 m apart on a frictionless table. A 10 bullet is fired at 400 m/s towards the blocks. It passes all the way through the first block, then embeds itself in the second block. The speed of the first block immediately afterwards is 6.0 m/s. What is the speed of the second block after the bullet stops in it? [KE2:9.48]

7. What impulse does the force shown in the figure exert on a 250 g particle? [K2E:9.3]
8. A 2.0 kg object is moving to the right with a speed of 1.0 m/s when it experiences a force shown in the figure. What are the object’s speed and direction after the force ends?

9. A tennis player swings her 1000 g racket with a speed of 10 m/s. She hits a 60 g tennis ball that was approaching her at a speed of 20 m/s. The ball rebounds at 40 m/s. [K2E:9.28]
   a) How fast is her racket moving immediately after the impact? (You can ignore the interaction of the racket with her hand for the brief duration of the collision.
   b) If the tennis ball and the racket are in contact for 10 ms, what is the average force that the racket exerts on the ball?
   c) How does the answer from part (b) compare to the gravitational force on the ball?

10. A particle of mass $m$ has an initial momentum vector $p_1 = mv_1$ as shown. After being given a sharp blow, the particle has a final momentum vector $p_2 = mv_2$. Draw on the figure a vector representing the impulse $J$ that must have been delivered to the particle by the sharp blow. Explain your reasoning.

11. Two pucks A and B, moving on a frictionless air table, have respective initial velocities $v_{1A}$ and $v_{1B}$. Puck A has twice the mass of puck B, and travels at half the speed. The pucks collide and stick together (this is called a "perfectly inelastic collision").

   a) Draw vectors $p_{1A}$ and $p_{1B}$ representing the *momenta* of the two bodies just before the collision.
b) Draw a vector $\mathbf{p}_1$ representing the total momentum of the system just before the collision. Then draw a vector $\mathbf{p}_2$ representing the total momentum of the system just \textit{after} the collision. Explain your reasoning.

c) What \textit{impulse} was imparted to the system (consisting of the two pucks) during the collision? Explain your reasoning.

12. A 1.0-kg steel ball and a 2.0-m cord of negligible mass make up a simple pendulum that can pivot without friction about the point O. This pendulum is released from rest in a horizontal position, and when the ball is at its lowest point it strikes a 1.0-kg block sitting at rest on a shelf. Assume that the collision is perfectly elastic and that the coefficient of kinetic friction between the block and shelf is 0.10.

a) What is the velocity of the block just after impact?

b) How far does the block slide before coming to rest (assuming that the shelf is long enough)?

13. Donna, who has mass 40 kg, is floating in a canoe of mass 10 kg at 5 m/s. Her brother, in a tree directly above, drops a sleeping bag of mass 5 kg into the canoe. (a) What is the speed of the canoe immediately after the sleeping bag lands? Explain. (b) An instant before the canoe immediately after the sleeping bag lands, the canoe was moving horizontally. After it lands it does not. Does this violate conservation of momentum? Explain. (c) A while later, Donna holds the sleeping bag out over the water and drops it. What is the speed of the canoe immediately after? Explain.

14. A hockey puck of mass $4m$ has been rigged to explode, as part of a practical joke. Initially the puck is at rest on a frictionless ice rink. Then it bursts into three pieces. One chunk, of mass $m$, slides across the ice at speed $v$. Another chunk, of mass $2m$, slides across the ice at $2v$. Adapted from: UCMerced Physics Discussion Worksheets
speed $2v$, in a direction at right angles to the direction of the first piece. From this information, find the velocity $v_f$ of the final chunk.

15. Two particles collide and bounce apart. The figure below shows the initial momenta of both and the final momentum of particle 2. What is the final momentum of particle 1? Write your answer in component form. [K2E:9.23]

16. A 300 g bird flying along at 6.0 m/s sees a 10 g insect heading straight toward it with a speed of 30 m/s. The bird opens its mouth wide and enjoys a nice lunch. What is the bird’s speed immediately after swallowing?

17. The figure shows a car, of mass $m = 1000$ kg, traveling east with a speed $v_o = 24$ km/h. At an intersection the car collides with a stationary bus having a mass $M = 2000$ kg. Immediately afterwards, the bus moves with a velocity $v_b = 5$ km/h at an angle 30° South of East. Find the velocity of the car immediately after the collision.

18. One billiard ball is shot west at 1.0 m/s. A second, identical billiard ball is shot west at 1.0 m/s. The balls have a glancing collision, not a head-on collision, deflecting the second ball by 90° and sending it north at 1.41 m/s. What are the speed and direction of the first ball after the collision? Give the direction as an angle south of east. [K2E:9.40]