1. An airplane has initial position 50.0 km north of the airport and flies at constant speed 375 km/h until reaching a position 30.0 km south of the airport 20.0 minutes later. (a) Find the displacement of the airplane. (b) Find the average velocity of the airplane.

2. At $t = 0$ a helicopter is located 100.0 km south of the airport and is traveling with constant velocity 45 m/s north. (a) Determine the position of the helicopter at $t = 5.0$ minutes. (b) Find the value of t when the helicopter reaches the airport.

3. A cyclist wants to cross a bridge with a narrow roadway along a busy road (because it is code red). The cyclist doesn't really want to die, so he is waiting for a "gap" in the traffic to cross the bridge. If the cyclist has speed v_1, the traffic has speed v_2, and the length of the bridge is distance d, what minimum time T must exist between passing cars ("gap" from one to the next)? Derive an expression for T in terms of v_1, v_2, and d.

4. What is the effect of speed on commute time? Suppose your daily commute consists of a distance x traveled at speed v_1, a stoplight of duration t_S, and a distance y traveled at speed v_2. (a) Derive expressions for the total time t and average speed v for the trip. (b) A typical commute has the following values: $x = 3200$ m, $v_1 = 15$ m/s, $t_S = 55$ s, and $y = 9600$ m. Use your results to calculate t and v for $v_2 = 25$ m/s, 30 m/s, and 35 m/s.

5. In science fiction spacecraft routinely travel at or beyond the speed of light, $c = 299\,792\,458$ m/s. In reality one of the fastest spacecraft to date is the robotic space probe New Horizons, which had top speed $v = 21$ km/s (during flyby of Jupiter). (a) Use each of these speeds to find travel time between Earth, $r = 1.00$ AU, and Pluto, $r = 39.5$ AU, convert to the most convenient unit. (b) The actual time to reach Pluto was 9.48 years. Use this to estimate the *average* speed of the New Horizons spacecraft and convert to mph.

6. The asteroid 99942 Apophis orbits the Sun along an elliptical path with major axis 1.844 AU, minor axis 1.810 AU, and circumference 5.740 AU. Its minimum, maximum, and average speeds are 25.32 km/s, 37.28 km/s, and 30.73 km/s. Find its average velocity and average acceleration one half its orbit, going from aphelion to its perihelion position of 0.746 AU, 331° from Sun.

7. The New Horizons spacecraft achieved a speed of 16 km/s at the end of its third stage, 44 minutes after launch. (a) Determine the average rate of acceleration. The initial acceleration at liftoff was 9.2 m/s^2. (b) At this rate, what is the 0 to 60 mph time? Are there any cars that can match this time?

8. A certain object has average acceleration a over time interval t. Half of this *time* it moves with constant speed v_1 but the other half it has a different constant speed. Determine the distance d that it travels in terms of these quantities and fundamental constants as necessary. Repeat with half the *distance* at different speed.

9. Two common tests of a car's ability to accelerate is to time it going from 0 to 60 mph and from 50 mph to 70 mph in top gear. Suppose the best times for a certain BMW are 4.9 s and 6.0 s respectively. Find the rate of acceleration for each trial. To aid in conversions: 1.00 mph = 0.447 m/s approx.

10. A car is headed east on a highway and undergoes an acceleration of 1.5 m/s^2 east for 3.0 s. (a) By how much does the speed of the car change? Is it an increase or decrease? The same car, still moving east, undergoes an acceleration of 5.0 m/s^2 west for 6.5 s, coming to a complete stop in the process. (b) What was the original speed of the car?

11. Starting at rest a car accelerates uniformly 5.00 m/s^2 eastward. Let this be $t = 0$. (a) Find the position and velocity at $t = 3.00$ s. (b) Find the distance traveled from $t = 3.00$ s to $t = 4.00$ s. (c) Find the speed at $t = 4.00$ s.

12. Suppose you are traveling 126 km/h on a roadway with speed limit 90.0 km/h when all of a sudden you notice a state trooper ahead. (a) If you slam on the brakes and decelerate 6.0 m/s^2 how much time would it take to slow to the speed limit? (b) How far would you travel in the process?

13. A certain car is reported by a magazine to complete a “standing quarter mile” in 14.5 seconds with an ending speed of 95 mph. (a) Determine the average acceleration. (b) Assuming the acceleration is constant calculate the distance the car should travel in 14.5 seconds. How does this compare with one quarter mile? Explain the discrepancy!

14. The catapult on an aircraft carrier must accelerate an F-18 Hornet to 78.2 m/s in a space of 94.2 m. What rate of acceleration is required? How many *g*’s is this? (1 $g = 9.8$ m/s^2)

15. A driver traveling at 25.0 m/s notices too late a stop sign 35.0 m ahead. After a "reaction time" of 0.20 s the brakes are applied and deceleration is 9.00 m/s per second. (a) Determine the speed of the car as it passes the stop sign. (b) At what initial speed would the driver have just been able to stop at the sign?

16. An elevator moves from the 1^{st} floor to the 9^{th} floor in 10.0 s – 1.50 s of this is spent accelerating and 2.00 s of this is spent stopping. Suppose the distance between each floor is 4.00 m. (a) Estimate the maximum speed of the elevator. (b) Estimate the maximum acceleration of the elevator. (c) Sketch three graphs for this motion: position, velocity, and acceleration vs. time. (d) What assumptions are made? How could the actual motion differ from that assumed? Discuss and explain.

17. A driving instructor tells his student to maintain a 2.00 second separation between the student's car and the car ahead. Suppose both cars are traveling at a steady 25.0 m/s. (a) How many meters apart are the two cars (i.e. what is the "following distance")? (b) If the trailing car brakes at 10.0 m/s^2, how much stopping distance is required? (c) Repeat (a) and (b) for two cars traveling at 50.0 m/s. (d) Supposing the trailing driver has a reaction time of 0.20 s, what is the maximum speed at which the "2.00 second rule" would give adequate separation of the cars to allow for stopping in an emergency?

18. (a) Repeat the previous problem symbolically and solve for the safe separation time, t, in simplest terms of reaction time, t_R, speed of the cars, v_o, and the deceleration rate, a. Check your expression by using the previous numerical values. (b) Repeat and suppose the leading car does not stop instantaneously but instead decelerates at rate a_2 and the trailing car decelerates at rate a_1.

19. A car is traveling at 25 m/s when an accident occurs. The car decelerates 3$\underline{0}$0 m/s^2 but the passenger does not slow down because he is not wearing a seatbelt. (a) Supposing the distance between the passenger and the dashboard is initially 0.50 m, what will be the speed of the car at the instant the passenger impacts the dash? (b) The difference in speeds is the "relatve speed" of the person's impact - what is this value? (c) How far has the car moved forward at the instant of impact. (d) At what minimum deceleration would the relative speed of impact be maximized?

20. A crazed soccer fan carouses in the street firing a pistol into the air. Ignore air resistance. (a) How high would the bullet go if it is fired with muzzle velocity 350 m/s upward? (b) What total time would it be in the air? (c) What would be the bullet’s velocity as it returns to the ground? (d) How would the actual motion of the bullet be different considering air resistance? Sketch the bullet’s height, velocity, and acceleration graphs and show theoretical vs. actual.

21. NASA has a research facility at which experimental packages in a spherical container undergo a freefall of 145 m in an evacuated tower. The container is stopped by a "catching device" that causes a deceleration of 245 m/s^2. (a) What is the maximum speed of the falling container? (b) What is the total time and distance of the container's downward motion?

22. Two rocks are released from the top of a building and fall to the street below. One rock is dropped from rest and simultaneously the other rock is thrown downward at 20.0 m/s. It is observed that one rock hits the street 1.00 seconds before the other. Determine the height of the building.