4.9 PROBLEMS

Problem 4.9.1. Suppose you live on the 5^{th} floor of a tall building. Your friend goes to the roof and drops a steel ball from rest while you time the ball as it falls. You find that the ball takes 0.110 sec to fall from the top of the window to the bottom of the window, a distance of 0.8 meter. How high above the top of the window of the 5^{th} floor is the roof?

Problem 4.9.2. A rocket is rising at a constant velocity of 200 m/s. A piece of the rocket comes loose and falls freely to the ground. It takes 50 sec for the piece to fall to the ground after dislodging from the rocket. How far above the ground the piece came loose?

Problem 4.9.3. A ball is tossed with a speed v_0 and caught at a height H above the launch point on its way down. Find the time the ball was in flight. Note: the velocity of the ball when caught is not zero.

Problem 4.9.4. A person P_1 at rest on the sidewalk observes that the rain drops are falling vertically with speed 10 m/s. What is the velocity of raindrops in the frame of another person P_2 who is running towards the person P_1 in the rain in a straight line with speed 5 m/s?

Problem 4.9.5. A person standing on the sidewalk at rest observes that rain drops are falling at 30° with respect to the vertical direction with speed 10 m/s. Assume the velocities of all rain drops fall in one plane. What is the velocity of the raindrops in the frame of a person that is running in the rain in a straight line with speed 5 m/s in a direction that is perpendicular to the plane containing the velocity vectors of the rain drops?

Problem 4.9.6. Two runners are running in the opposite directions on a 400-m closed track with different speeds, which can be assumed to be constant. Let $t = 0$ be the time when they first pass each other, and let the distances be measured from that point O on the path. They are next seen to pass each other 180 m from O as measured on the track. (a) How far from O will they pass each other next? (b) If the speed of the faster runner is 8 m/s, what is the speed of the slower runner? (c) Let t_n be the n^{th} time they will pass each other. Find a formula for t_n.

Problem 4.9.7. The shadow of a pendulum cast on a flat board moves on a straight line. By placing the x-axis on the straight line with the origin at the middle of the total path, the x-coordinate of the shadow is given by $x(t) = 50\cos(\pi t)$, where t is in seconds and x is in cm. (a) Find the speed of the shadow at (i) $t = \frac{1}{4}$ sec and (ii)$t = \frac{1}{2}$ sec. (b) Find the acceleration of the shadow's motion at $t = \frac{1}{3}$ sec. (c) How much distance does the shadow travel in 20 sec?

Problem 4.9.8. An ant is moving in a straight line with a variable speed. It covers the first meter in 5 sec, the next $\frac{1}{2}$ m in 5 *sec*, the next $\frac{1}{4}$ m also in 5 sec, and so on. That is, the ant covers $\frac{1}{2}$ of the previous step in the same amount of time as the last step. (a) How much distance would the ant travel in all before finally coming to rest? (b) How much time does the ant take to reach its final destination? (c) What is the average speed of the ant?

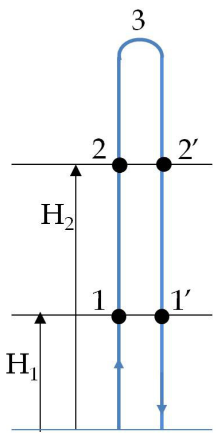

Figure 4.23: Problem 4.9.9.

Problem 4.9.9. One way to measure the value of g is to launch a projectile vertically upward and record the return times at two different heights. Let T_1 and T_2 be the two return times, i.e.,the time for 1-3-1' and 2-3-2', at heights H_1 and H_2 respectively as shown in Fig. 4.23. Deduce the following formula for g from the heights and times.

$$g = \frac{8\,(H_2 - H_1)}{T_1^2 - T_2^2}.$$

Problem 4.9.10. An insect flies at a constant speed between two moving walls that are initially a distance D apart with the insect near one wall. The insect goes from one wall to the other and back without losing anytime in the turn around, and does this continuously. If both the walls move right with a constant speed u with respect to the floor and the insect's speed be v, find the distance the insect has traveled by the N^{th} turn around. Assume that at $t = 0$ the insect is moving to the right from its position just to the right of the left wall. Think of other variations of this problem, and work them out for fun.

Problem 4.9.11. A projectile is fired with speed v_0 at an angle θ from the horizontal. (a) Show that the horizontal distance D traveled by the projectile before landing at the same height from the ground is given by

$$D = \frac{v_0^2 \sin(2\theta)}{g}.$$

(b) From this formula, prove that the range is maximum when $\theta = 45°$.

Problem 4.9.12. A cannon is on an incline with an angle of inclination φ as shown in Fig. 4.24. A cannonball is fired with a speed v_0 at an angle θ with respect to the incline. The ball comes out of the cannon at a height h. How far up on the incline will the ball land if the air resistance is ignored?

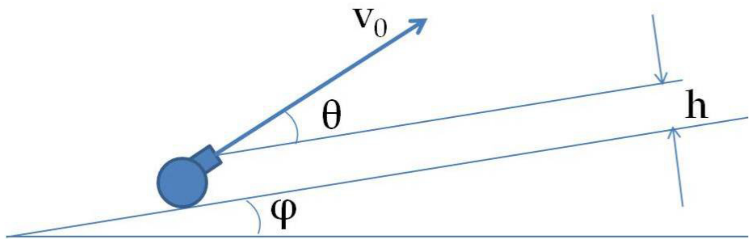

Figure 4.24: Exercise 4.9.12.