Kinematics Problems

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1 Problems

These problems have been adapted from the sources listed in parentheses. For all problems, you can assume $g = 10\ \text{m/s}^2$ to simplify arithmetic. Ignore effects of air resistance unless otherwise specified.

1. (HRK Ch 2 MC - No. 9)
   Bryan makes the following claim: "A freely falling object falls a greater distance during each second than the total distance fallen in all previous seconds." Bryan's statement

   (A) is always true
   (B) is true only for sufficiently short times
   (C) is true only for sufficiently long times
   (D) is never true

2. (HRK Ch 2 Exercises - No. 53)
   At a construction site Larry drops a pipe wrench that strikes the ground with a speed of 24.0 m/s. From what height did Larry drop it, and how long was it falling?

3. (Morin, Problems and Solutions in Introductory Physics)
   Two trains, A and B, travel in the same direction on the same set of tracks. A starts at rest at position d, and B starts with velocity v_0 at the origin. A accelerates with acceleration a, and B decelerates with acceleration $-a$. What is the maximum value of v_0 (in terms of d and a) for which the trains don't collide?

4. (HRK Ch 4 Problems - No. 21)
   Anya is whirling a stone in a horizontal circle 1.9 m above the ground by means of a string 1.4 m long. The string breaks, and the stone flies off horizontally, almost hitting Amrita, before striking the ground 11 m away. What was the centripetal acceleration of the stone while in circular motion?

5. (Ontario Association of Physics Teachers, 2006 contest)
   You are standing on a river bank. The river is flowing at a rate of 2.0 m/s. You see Nafi floating in the river without swimming, and being carried by the river downstream. You throw two pieces of bread at Nafi. One piece lands upstream of Nafi, and the other downstream equal distance. Nafi can swim at 1.0 m/s. Nafi is hungry, and wants to reach the (soggy) bread in the shortest amount of time. What should he do? Assume the bread does not sink before Nafi can reach it.

6. (HRK Ch 2 Problems - No. 32)
   Kevin was trying to recreate Galileo's Leaning Tower of Pisa experiment and decided to drop two objects from the top of the tower (about 56 m tall). If he released one slightly sooner than the other with a time difference of 0.1 s, then what would be the vertical separation of the objects just before the first one hit the ground?

7. (Not entirely sure of the source)
   A 600 m wide river flows directly south at 4.0 m/s. Connor is driving a small motor boat at 5.0 m/s in still water and points in such a direction so that it will travel directly east relative to the land. How long does it take Connor to cross the river?

8. (Ontario Association of Physics Teachers 2012 Contest)
Anya went skydiving and stepped out of an airplane at an altitude of 1000 m. She fell freely for 5.00 s. She opened her parachute and slowed to 7.00 m/s in a negligible time. She then maintained this speed until she reached the ground. What was the total elapsed time from leaving the airplane to landing on the ground?

9. (HRK Ch 4 Exercises - No. 13)
Amrita saw a ball roll off a horizontal tabletop, 25.0 m high. It struck the floor at a point 2.5 m away from the table edge. What was the ball's initial horizontal speed?

10. (Morin, Problems and Solutions in Introductory Physics)
Larry's front-loading washing machine has radius of 0.3 m and a spin cycle of 1000 revolutions per minute. What is the acceleration of a point on the surface of the drum at this spin rate?

11. (HRK Ch 4 Problems - No. 9)
Bryan is a kicker on a football team, and can kick a football with initial speed 25.0 m/s. What are the greatest and least angles that he must kick the ball to just score a field goal from a point 50 m in front of the goalposts whose horizontal bar is 3.44 m above the ground?

12. (Morin, Problems and Solutions in Introductory Physics)
Kevin is a movie director and wants a scene in which a car appears to fly off a cliff at 50 mph. To simulate this, the Kevin will make a 1/100 scale model of a car and cliff, and have the model car fly off the model cliff. By what factor should the film be sped up or slowed down in order to look realistic, and what should the real speed of the toy car be as it approaches the cliff?

13. ($F = ma$ 2008 No. 6)
Nafi's cannon fires projectiles on a flat range at a fixed speed but with variable angle. The maximum range of the cannon is L. What is the range of the cannon when it fires at an angle $\pi/6$ above the horizontal in terms of L? Ignore air resistance.

14. (AP Exam FR 1979)
Connor releases a ball of mass m from rest at a distance h above a frictionless plane inclined at an angle of 45° to the horizontal as shown above. The ball bounces horizontally off the plane at point $P1$ with the same speed with which it struck the plane and strikes the plane again at point $P2$. In terms of g and h determine the time the ball is in flight between points $P1$ and $P2$ and the distance L along the plane from $P1$ to $P2$.

15. ($F = ma$ 2007 No. 17)
Amrita throws a small object horizontally off of a 50 m high building with an initial speed of 10 m/s. The object falls freely under the influence of gravity. At any point along the trajectory, the acceleration due to gravity can be broken into a component tangential to the trajectory and a component perpendicular to the trajectory. How many seconds after the object is thrown is the tangential component of the acceleration of the object equal to the perpendicular component of the acceleration of the object? Ignore air resistance.

16. (Courtesy of Dr. Dell)
Bryan is driving at a constant speed s when he passes a robocop initially at rest. The robocop begins his chase by first accelerating at a for a time t, then accelerating at $-a$ until he catches up to Bryan. At that moment, both are moving at the same speed. Find a in terms of s and t.

17. (Classic)
Connor has two identical balls labeled A and B and throws them off a cliff of height h. He throws them off with the same initial speed v_0 but ball A is launched off at an angle α above the horizontal and ball B is launched off at angle β below the horizontal. Let v_A and v_B the final speeds of balls A and B as they hit the ground, respectively. Find $v_A - v_B$.