Problem Set: Kinematics in 1 Dimension

Name: **Date:**

Solve the following problems and answer the questions on separate paper. Be neat and complete. Include units, set-ups, etc.

1. As you left your home one morning, your bus was 20.0m away and just starting to pull away from the bus stop at $4.00 m/s^2$. You start running at a constant speed toward the bus, catching up with it 5.00 seconds later. How fast did you run? ***(14.0m/s)***

   $x = 0 + 1/2\ (4.00 m/s^2)(5.00 s)^2 = 50.0 m$ = distance the bus travels

   distance you ran = 20.0m + 50.0m = 70.0m

   $70.0 m \div 5.00 s = 14.0 m/s$ (= 50.4km/h = 30.3mph)

2. A bicyclist is approaching an intersection traveling at a constant 8.00m/s. Just ahead of the bicyclist, a car is stopped at a red light. When the cyclist is next to the car, the light turns green, so she continues as before, passing the car. Meanwhile the car starts to accelerate at a rate of $4.00 m/s^2$ until it reaches its cruising speed of 16.0m/s. At what time (other than at t = 0s) are the car and the bicyclist next to each other? ***(4.00s)***

   $(8.00 m/s)\ t = 0 + 1/2(4.00 m/s^2)(t)^2$ [bike distance zero accel = car distance uniform accel]

   $8t = 2t^2$ $t = 4.00 s$

   bike: $4.00 s \times 8.00 m/s = 32.0 m$ @ 4.00s

   car: $x = 0 + 1/2\ (4.00 m/s^2)(4.00 s)^2 = 32.0 m$ @ 4.00s

3. A toy car is pushed from rest so that it accelerates at $2.00 m/s^2$ for 1.50s, then slows down at $1.00 m/s^2$ until it stops. What is (a) the maximum speed of the toy car, (b) the time it takes to slow down and stop, and (c) the total distance traveled by the car? ***(3.00m/s, 3.00s, 6.75m)***

   (a) $v = 0 + (2.00 m/s)(1.50 s) = 3.00 m/s$

   (b) $0 = 3.00 m/s + (-1.00 m/s^2)\ t$ $t = 3.00 s$

   (c) speeding up: $x = 0 + 1/2\ (2.00 m/s^2)(1.50 s)^2 = 2.25 m$

   slowing down: $x = (3.00 m/s)(3.00 s) + 1/2\ (-1.00 m/s^2)(3.00 s)^2 = 4.50 m$

   total distance = 2.25m + 4.50m = 6.75m

4. A ball is dropped from an unknown height, accelerating at $9.81 m/s^2$ downward until it hits the ground 2.00 seconds later. After hitting the ground the ball rebounds at half the speed it had just prior to hitting the ground. (a) When does the ball first come to rest after first hitting the ground, with respect to the initial drop time, t = 0s? (b) How high does the ball rebound? ***(3.00s, 4.90m)***

   $v = 0 + (-9.81 m/s^2)(2.00 s) = -19.6 m/s$ as it hits the ground

   so it rebounds at 9.80m/s and goes upward until it slows down and reaches a speed of 0m/s

   (a) $0 = 9.80 m/s + (-9.81 m/s^2)(t)$

   $t = 1.00 s$ So the total time is 2.00s + 1.00s = 3.00s

   (b) $x = 9.80 m/s\ (1.00 s) + 1/2\ (-9.81 m/s^2)(1.00 s)^2 = 4.90 m$

5. You are driving down a straight road at a constant 54.0 km/h (15.0m/s). When you are 30.0m from a side street, a car abruptly pulls out in front of you and stops. If it takes you 1.00s to react to the car and if your maximum acceleration is 5.00m/s^2, can you stop in time to avoid an accident. Show all work to support your answer. ***(An accident will occur.)***

   v_o = 15.0m/s   x = 30.0m   a = -5.00m/s^2

   In 1.00s to react, you have traveled: 15.0m/s x 1.00s = 15.0m

   Distance remaining to travel: 30.0m = 15.0m = 15.0m (until you hit the car)

   t = (v - v_o) / a = (0 - 15.0m/s) / -5.00m/s^2 = 3.00s to stop (at maximum negative acceleration)

   x = (15.0m/s)(3.00s) + 1/2 (-5.00m/s^2)(3.00s)^2 = 22.5

   So the minimum distance needed to stop with maximum negative acceleration is 22.5m, but you only have 15.0m.

   An accident WILL occur.

6. You and your friend are talking on the sidewalk. When you are finished talking, she starts walking home at 2.20m/s, and you start riding your bike at 4.00m/s in the opposite direction. 10.0 seconds later, you realize you forgot to tell her something, so you reverse direction and ride at 6.00m/s toward her. (a) How long does it take to catch up to your friend? (b) Where is your friend at that time? *(Ignore the time it takes to turn around.)* ***(26.3s after you left your friend, 57.9m)***

   (a) (4.00m/s) (10.0s) + (-6.00m/s)(t - 10.0s) = (-2.20m/s)(t)

   40.0 + 60.0 - 6.00t = -2.20t

   100.0 = 3.80 t

   26.3s = t

   (b) 26.3s x 2.20m/s = 57.9m away from where the friends left one another

7. A girl stands at the edge of the top of a 100.0 m cliff and throws a ball upward with a speed of 20.0m/s. She does not catch the ball on its descent and the ball falls to the ground below. (a) What is the total time of flight? (b) How fast is it going just before it hits the ground. Assume the acceleration is only due to gravity and the acceleration due to gravity is 9.81m/s^2 in the downward direction. ***(6.99s, -48.6m/s)***

   Going upward:

   0 = 20.0m/s + (-9.81m/s^2)(t)   t = 2.04s (time to go upward and reach a speed of 0m/s)

   x = (20.0m/s)(2.04s) + 1/2 (-9.81m/s^2)(2.04s)^2 = 20.4m   Goes upward 20.4m (max height)

   Going downward:

   height to fall is 100.0m + 20.4m = 120.4m (downward)   it's initial dropping velocity = 0m/s

   -120.4m = 0 + 1/2 (-9.81m/s^2)(t)^2 t = 4.95s

   (a) total time = 2.04s + 4.95s = 6.99s

   (b) v = 20.0m/s + (-9.81m/s^2)(6.99s) = -48.6m/s or 48.6m/s in the downward direction

8. A ball is dropped from rest from the top of a tall building. Someone on a floor below sees the ball pass by a 1.50m tall window (height from top to bottom) in 0.200s. What is the distance from the top of the building to the top of the window? Assume the acceleration is only due to gravity and the acceleration due to gravity is 9.81m/s^2 in the downward direction. ***(2.17m below the top of the building)***

   -1.50m = v_o(0.200s) + 1/2 (-9.81m/s^2)(0.200s)^2 (-1.50m because it is falling downward)

   -6.52m/s = v_o at the top of the window

   So it started at 0m/s and was traveling -6.52m/s when it hit the top of the window. So how long did it take to get to the top of the window?

   -6.52m/s = 0 + (-9.81m/s^2)(t) t = 0.665s (time to get to the top of the window)

   x = (0)(0.665s) + 1/2 (-9.81m/s^2)(0.665s)^2 x = -2.17m

   So the top of the window is 2.17m below the top of the building from which the ball was released.

9. The space shuttle Kinematica is 1300.m away from the dock of a space station and approaching at 160.0m/s. The shuttle pilot can give the shuttle a constant acceleration by firing the engines. What constant acceleration should she set so that the shuttle comes to rest right at the dock? ***(-9.82m/s^2 - she's slowing the ship down)***

   a = -160.0/t

   1300.m = 160.0m/s (t) + 1/2 (-160.0/t)(t^2)

   1300.m = 160.0t + (-80.00t) t = 16.3 s

   0 = 160.0m/s + (a)(16.3s) a = -9.82m/s^2

10. A truck and a sports car are side-by-side at one end of a long straight road. The truck starts from rest at t = 0s and accelerates at 1.50m/s^2. The sports car starts from rest at t = 8.00 and accelerates at 3.50m/s^2. (a) At what time is the sports car's speed equal to the truck's? (b) What is that speed? (c) At what time are they side-by-side? (d) How far have they traveled when they are side-by-side? ***(14.0s, 21.0m/s, 23.2s, 404m)***

    (a) $v_{TRUCK} = v_{CAR}$

    (1.50m/s^2)(t = (3.50m/s^2)(t - 8.00s)

    1.50t = 3.50t - 28.0 t = 14.0s

    (b) v = (1.50m/s^2)(14.0s) = 21.0m/s

    (c) $x_{TRUCK} = x_{CAR}$

    1/2(1.50m/s^2)(t^2) = 1/2(3.50m/s^2)(t - 8.00s)^2

    0.750t^2 = 1.75(t^2 - 16.0t + 64.0) OR 0 = 1.00t^2 - 28.0t + 112

    t = 4.84s or 23.2s can't be less than 8.00s so t = 23.2s

    (d) x = 1/2 (1.50m/s^2)(23.2s)^2 = 404m

11. An accident nearly occurred this morning near the hospital. A car was driving along, and the driver did not see a pedestrian crossing the road until it was almost too late. He slammed on the brakes sliding to a stop 2.00m away from the pedestrian, creating a skid mark 15.2m long. (a) If the speed limit near the hospital is 20.0mph (8.94m/s) and the maximum acceleration possible for the car is 6.00m/s^2, was the driver speeding or not? (b) How fast was the driver going just before he applied the brakes? (c) If the driver had reacted a little too late, he would have hit the pedestrian. How much more time did the driver have to react without hitting the pedestrian? ***(he was speeding, 13.5m/s, 0.153s)***

(a) max skid from max speed and max acceleration

$0 = 8.94\text{m/s} + (-6.00\text{m/s}^2)(t)$ $\quad t = 1.49\text{s}$

$x = (8.94\text{m/s})(1.49\text{s}) + 1/2\ (-6.00\text{m/s}^2)(1.49\text{s})^2$ $\quad x = 6.60\text{m}$

6.60m is the max skid if not speeding, since the skid was 15.2m, the driver was speeding

(b) $0 = v_O + (-6.00\text{m/s}^2)(t)$ $\quad v_O = 6.00t\ \text{m/s}^2$

Find t using skid length and (-) acceleration since the car is slowing down

$15.2\text{m} = (6.00t\ \text{m/s}^2)(t) + 1/2\ (-6.00\text{m/s}^2)(t)^2$

$15.2\text{m} = 3.00t^2\ \text{m/s}^2$ $\quad t = 2.25\text{s}$

$v_O = 6.00t\ \text{m/s}^2 = (6.00 \times 2.25) = 13.5\ \text{m/s}$

(c) $2.00\text{m} = (13.5\text{m/s})(t) + 1/2\ (-6.00\text{m/s}^2)(t)^2$

QUADRATIC: $t = 0.153\text{s}$ - OR - 4.35s

4.35s is too larger so $t = 0.153\text{s}$

12. Sam throws a water balloon upwards (from ground level) with an initial speed of 35.0m/s. *(Recall the acceleration due to gravity is 9.81m/s^2 in a downward direction.)*

(a) For how many seconds will it be rising? ***(3.57s)***

$v = v_o + at$ $\quad 0 = 35.0\text{m/s} + (-9.81\text{m/s}^2)t$ $\quad t = 3.57\text{s}$

(b) What is its total time in the air? ***(7.14s)***

3.57s is half-time so total time is $(3.57\text{s} \times 2) = 7.14\text{s}$

(c) What is its maximum height? ***(62.4m)***

$x = v_ot + \frac{1}{2}at^2$ $\quad x = (35.0\text{m/s})(3.57\text{s}) + \frac{1}{2}(-9.81\text{m/s}^2)(3.57\text{s})^2$ $\quad x = 62.4\text{m}$

(d) At what instant(s) will it be 20.0m above the ground? ***(6.50s and 0.632s)***

$20.0\text{m} = (35.0\text{m/s})t = \frac{1}{2}(-9.81\text{m/s}^2)t^2$ $\quad 4.91t^2 - 35.0t + 20.0 = 0$ $\quad$ solve quadratic

$t = 6.50\text{s}$ and $t = 0.632$

(e) How far does the water balloon travel in its 3rd second of travel? ***(10.5m)***

$t = 2.00\text{s}$ $\quad x = (35.00\text{m/s})(2.00\text{s}) + \frac{1}{2}(-9.81\text{m/s}^2)(2.00\text{s})^2$ $\quad x_2 = 50.4\text{m}$

$t = 3.00\text{s}$ $\quad x = (35.00\text{m/s})(3.00\text{s}) + \frac{1}{2}(-9.81\text{m/s}^2)(3.00\text{s})^2$ $\quad x_2 = 60.9\text{m}$

$\Delta x = 60.9\text{m} - 50.4\text{m} = 10.5\text{m}$

1. Maks stands at the top of a cliff that is 80.0m high. He drops one rock (initial speed is 0m/s) and picks up another rock in time to throw it downward 2.00 seconds later with a certain non-zero initial speed. The two rocks hit the ground below the cliff at exactly the same time. With what initial speed did Maks thrown the second rock? (Recall: the acceleration due to gravity is $9.81 m/s^2$ in the downward direction.) ***(29.2m/s)***

Rock 1: the rock that was dropped $x = -80.0m$ $a = -9.81 m/s^2$ $v_o = 0 m/s$

$x = v_o t + \frac{1}{2} a t^2$ $-80.0m = 0 + \frac{1}{2}(-9.81 m/s^2)(t)^2$ $t = 4.04s$

So Rock 2 took (4.04s - 2.00s) = 2.04s to hit the ground

Rock 2: the rock that was thrown $x = -80.0m$ $a = -9.81 m/s^2$ $t = 2.04s$

$x = v_o t + \frac{1}{2} a t^2$ $-80.0m = v_o(2.04s) + \frac{1}{2}(-9.81 m/s^2)(2.04s)^2$ $v_o = 29.2\ m/s$

2. A hot air balloon is released from rest on the ground but, during its ascent, Hunter the pilot realizes that she has forgotten her lunch and yells for her assistant to throw it to her before the balloon gets too high. The balloon rises with a uniform acceleration of $2.00\ m/s^2$. 5.00 seconds into the flight the assistant finally throws the lunch pail vertically upward with a speed of 35.0m/s. Hunter the balloonist catches the lunch pail while it is still rising upward. *Remember that the acceleration due to gravity (acting on the lunch) is $-9.81 m/s^2$.*

(a) What is the balloon's speed at the time the lunch is launched upward? ***(10.0m/s)***

$v = 0 + (2.00 m/s^2)(5.00s)$ $v = 10.0 m/s$

(b) How high is the balloon at the time the lunch is launched upward? ***(25.0m)***

$x = 0 + \frac{1}{2}(2.00 m/s^2)(5.00s)^2$ $x = 25.0m$

(c) At what time is the lunch pail caught after the balloon is initially launched? ***(6.62s)***

balloon is already 25.0m high and continuing to travel with an "initial" speed of 10.0m/s

How long does it take for the distance of the balloon and the distance of the lunch to be the same (=).

$25.0m + (10.0 m/s)t + \frac{1}{2}(2.00 m/s^2) t^2 = (35.0 m/s)t + \frac{1}{2}(-9.81 m/s^2) t^2$

$25 + 10t + t^2 = 35t + (-4.91)t^2$

$5.91t^2 - 25t + 25 = 0$ quadratic $t = 1.62s$ (as it goes up) and $t = 2.61s$ (as it falls down)

since she catches the lunch on the way up . . .

total time in the air = 5.00 + 1.62s = 6.62s

(d) At what height above the ground does Allison catch the lunch pail? ***(43.8m)***

$x = 0 + \frac{1}{2}(2.00 m/s^2)(6.62s)^2 = 43.8m$

3. Brilliant science student, Rachel, having finished her day of physics and chemistry classes, is running to catch a bus that is stopped at the bus stop. She is running with a constant speed of 4.00m/s and is 20.0m away from the bus when the bus begins to accelerate with uniform acceleration of 1.00m/s^2. Undaunted she continues to run in hopes of catching the moving bus.
   (a) If the bus continues to accelerate at its constant rate and Rachel maintains her constant speed of 4.00m/s, does she catch the bus? Show your work to support your answer. ***(NO)***
   (b) If Rachel fails to catch the bus, what is her "frustration" distance (i.e. how close does she get to the bus)? ***(12.0m)***
   (c) If 20.0m was too far to overcome, how close to the bus did Rachel have to be (when it started to accelerate) to insure that she catches the bus if the other conditions remain the same? ***(8.0m)***
   (d) If Rachel has 20.0m to overcome, what ***maximum acceleration*** of the bus would have allowed Rachel to catch the bus? How many seconds would it have taken for this to occur? ***(0.400m/s^2 and 10.0s)***
   (e) Assuming the original conditions, what minimum constant speed would Rachel need in order to allow her to catch the bus? ***(6.32m/s)***

(a) If the bus has a velocity greater than Rachel, then she will definitely be unable to catch the bus, so she needs to catch the bus before it goes faster than 4.00m/s. So . . .

$v = v_o + a\,t$ $\quad$ $t = (v - v_o) \div a = (4.00\text{m/s} - 0\text{m/s}) \div 1\text{m/s}^2 = 4.00\text{s}$

So the girl needs to catch the bus in the first 4.00s. In 4.00s Rachel travels:

4/00m/s x 4.00s = 16.00m

But the bus is already 20.0m ahead, so Rachel does NOT catch the bus.

(b) The closest Rachel can get to the bus is just as the bus is at 4.00m/s, or (because of its acceleration rate) at 4.00seconds.

Bus ⇒ $x = 20.0\text{m} + \tfrac{1}{2}(1.00\text{m/s}^2)(4.00\text{s})^2 = 28.0\text{m}$ $\quad$ Rachel ⇒ $x = (4.00\text{m/s})(4.00\text{s}) = 16.0\text{m}$

So 28.0m - 16.0m = 12.0m apart = frustration distance

(c) Since Rachel was at 20.0m away from the bus but ended up at the closest point only 12.0m away, she would have needed the bus to be only 8.0m away at the start so that she could have caught up with the bus.

(d) Rachel needs to cover the 20.0m and she has to do it before the bus exceeds a 4.00m/s speed so . . .

$v^2 = v_o^2 + 2\,a\,x$ $\quad$ $(4.00\text{m/s})^2 = 0 + 2\,(a)\,(20.0\text{m})$ $\quad$ $a = 0.400\text{m/s}^2$

$v = v_o + a\,t$ $\quad$ $t = (v - v_o) \div a = (4.00\text{m/s} - 0) \div 0.400\text{m/s}^2 = 10.0\text{s}$

(e) Rachel covers the same distance as the bus plus an additional 20.0m and Rachel has to catch up to the bus before it goes faster than her constant speed so . . .

$v^2 = v_o^2 + 2\,a\,x$ $\quad$ $v^2 = 0 + 2\,(1.00\text{m/s}^2)(20.0\text{m})$

$v = 6.32$m/s is the minimum speed Rachel would need