

# Physics 4A

## Chapter 2 HW Solutions

### Chapter 2

Conceptual Questions: 8, 11, 12

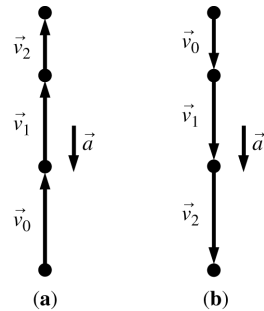
Problems: 19, 22, 23, 29, 39, 48, 55, 63, 65

**CQ 2.8. (a)** The positions of the third dots of both motion diagrams are the same, as are the sixth dots of both, so cars A and B are at the same locations at the time corresponding to dot 3 and again at that of dot 6.

**(b)** The spacing of dots 4 and 5 in both diagrams is the same, so the cars are traveling at the same speeds between times corresponding to dots 4 and 5.

**CQ 2.11. (a)** As a ball tossed upward moves upward, its vertical velocity is positive, while its vertical acceleration is negative, opposite the velocity, causing the ball to slow down.

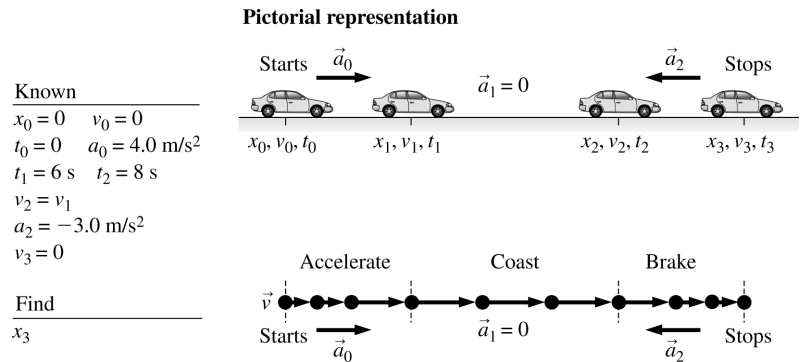
**(b)** The same ball on its way down has downward (negative) velocity. The downward negative acceleration is pointing in the same direction as the velocity, causing the speed to increase.



**CQ 2.12.** For all three of these situations the acceleration is equal to  $g$  in the downward direction. The magnitude and direction of the velocity of the ball do not matter. Gravity pulls down at constant acceleration. (Air friction is ignored.)

**2.19. Model:** The car is a particle moving under constant-acceleration kinematic equations.

**Visualize:**



**Solve:** This is a three-part problem. First the car accelerates, then it moves with a constant speed, and then it decelerates.

First, the car accelerates:

$$v_1 = v_0 + a_0(t_1 - t_0) = 0 \text{ m/s} + (4.0 \text{ m/s}^2)(6 \text{ s} - 0 \text{ s}) = 24 \text{ m/s}$$

$$x_1 = x_0 + v_0(t_1 - t_0) + \frac{1}{2}a_0(t_1 - t_0)^2 = 0 \text{ m} + \frac{1}{2}(4.0 \text{ m/s}^2)(6 \text{ s} - 0 \text{ s})^2 = 72 \text{ m}$$

Second, the car moves at  $v_1$ :

$$x_2 - x_1 = v_1(t_2 - t_1) + \frac{1}{2}a_1(t_2 - t_1)^2 = (24 \text{ m/s})(8 \text{ s} - 6 \text{ s}) + 0 \text{ m} = 48 \text{ m}$$

Third, the car decelerates:

$$v_3 = v_2 + a_2(t_3 - t_2) \Rightarrow 0 \text{ m/s} = 24 \text{ m/s} + (-3.0 \text{ m/s}^2)(t_3 - t_2) \Rightarrow (t_3 - t_2) = 8 \text{ s}$$

$$x_3 = x_2 + v_2(t_3 - t_2) + \frac{1}{2}a_2(t_3 - t_2)^2 \Rightarrow x_3 - x_2 = (24 \text{ m/s})(8 \text{ s}) + \frac{1}{2}(-3.0 \text{ m/s}^2)(8 \text{ s})^2 = 96 \text{ m}$$

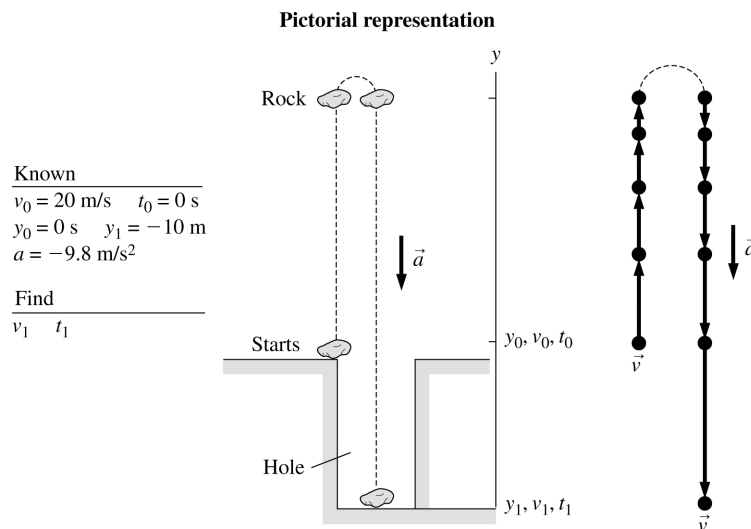
Thus, the total distance between stop signs is:

$$x_3 - x_0 = (x_3 - x_2) + (x_2 - x_1) + (x_1 - x_0) = 96 \text{ m} + 48 \text{ m} + 72 \text{ m} = 216 \text{ m}$$

**Assess:** A distance of approximately 600 ft in a time of around 10 s with an acceleration/deceleration of the order of 7 mph/s is reasonable.

**2.22. Model:** We will use the particle model and the constant-acceleration kinematic equations.

**Visualize:**



**Solve:** (a) Substituting the known values into  $y_1 = y_0 + v_0 \Delta t + \frac{1}{2} a \Delta t^2$ , we get

$$-10 \text{ m} = 0 \text{ m} + 20 \text{ (m/s)}t_1 + \frac{1}{2}(-9.8 \text{ m/s}^2)t_1^2$$

One of the roots of this equation is negative and is not relevant physically. The other root is  $t_1 = 4.53 \text{ s}$ , which is the answer to part (b). Using  $v_1 = v_0 + a \Delta t$ , we obtain

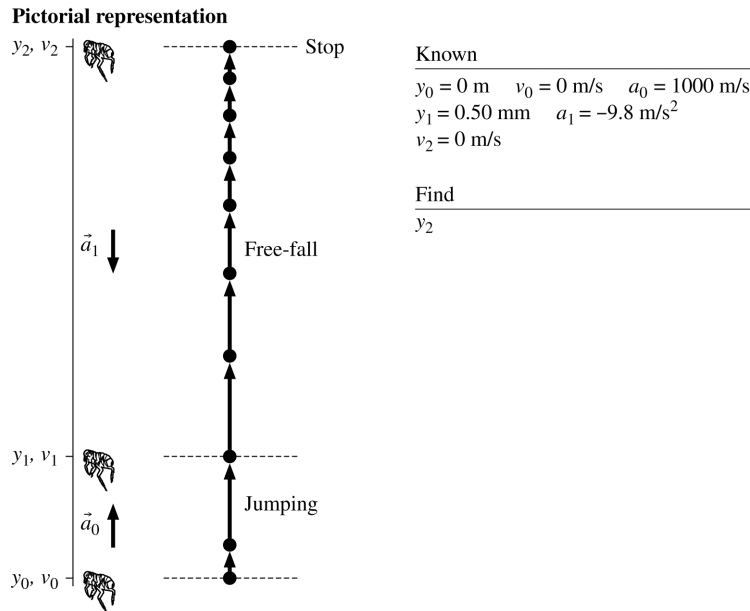
$$v_1 = 20 \text{ (m/s)} + (-9.8 \text{ m/s}^2)(4.53 \text{ s}) = -24 \text{ m/s}$$

(b) The time is 4.5 s.

**Assess:** A time of 4.5 s is a reasonable value. The rock's velocity as it hits the bottom of the hole has a negative sign because of its downward direction. The magnitude of 24 m/s compared to 20 m/s, when the rock was tossed up, is consistent with the fact that the rock travels an additional distance of 10 m into the hole.

**2.23. Model:** Model the flea as a particle. Both the initial acceleration phase and the free-fall phase have constant acceleration, so use the kinematic equations.

**Visualize:**



**Solve:** We can apply the kinematic equation  $v_f^2 - v_i^2 = 2a\Delta y$  twice, once to find the take-off speed and then again to find the final height. In the first phase the acceleration is up (positive) and  $v_0 = 0$ .

$$v_1^2 = 2a_0(y_1 - y_0) = 2(1000 \text{ m/s}^2)(0.50 \times 10^{-3} \text{ m}) \Rightarrow v_1 = 1.0 \text{ m/s}$$

In the free fall phase the acceleration is  $a_1 = -g$  and  $v_1 = 1.0 \text{ m/s}$  and  $v_2 = 0 \text{ m/s}$ .

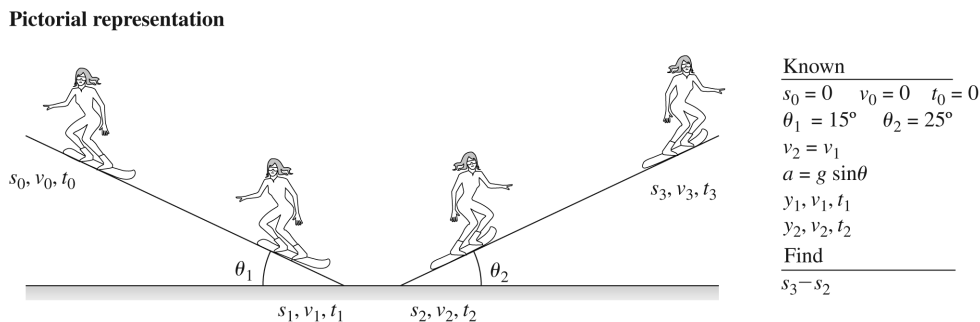
$$y_2 - y_1 = \frac{v_2^2 - v_1^2}{2a_1} = \frac{-v_1^2}{2(-g)} = \frac{-(1.0 \text{ m/s})^2}{2(-9.8 \text{ m/s}^2)} = 5.1 \text{ cm}$$

So the final height is  $y_2 = 5.1 \text{ cm} + y_1 = 5.1 \text{ cm} + 0.50 \text{ mm} = 5.2 \text{ cm}$ .

**Assess:** This is pretty amazing—about 10–20 times the size of a typical flea.

**2.29. Model:** The snowboarder is a particle moving under constant-acceleration kinematic equations. The speed does not diminish on the horizontal section.

**Visualize:** Note that our  $s$ -axis is positioned along both inclines.



**Solve: (a)** Using the following kinematic equation for the downward slope

$$v_1^2 = v_0^2 + 2a_0(s_1 - s_0) = (0 \text{ m/s})^2 + 2(9.8 \text{ m/s}^2)(\sin 15^\circ)(50 \text{ m} - 0 \text{ m}) \Rightarrow v_1 = 15.93 \text{ m/s}$$

which is reported as 16 m/s to two significant figures.

**(b)** Use the same equation again on the upward slope (with  $v_2 = v_1$ ).

$$v_3^2 = v_2^2 + 2a_2(s_3 - s_2) = (0 \text{ m/s})^2 \Rightarrow$$

$$(s_3 - s_2) = \frac{-v_1^2}{2a_2} = \frac{-(15.93 \text{ m/s})^2}{2(-9.8 \text{ m/s}^2)(\sin 25^\circ)} = 31 \text{ m}$$

**Assess:** Because the upward slope is steeper we did not expect the snowboarder to travel as far up the slope.

**2.39. Solve:** The given function for the velocity is  $v_x = t^2 - 7t + 10$ .

(a) The turning points are when the velocity changes sign. Set  $v_x = 0$  and check that it actually changes sign at those times. The function factors into the product of two binomials:

$$v_x = (t - 2)(t - 5) \Rightarrow v_x = 0 \text{ when } t = 2 \text{ s and } t = 5 \text{ s}$$

Indeed, the function changes sign at those two times.

(b) The acceleration is given by the derivative of the velocity.

$$a_x = \frac{dv_x}{dt} = 2t - 7$$

Plug in the times from part (a):  $a_x(2 \text{ s}) = 2(2) - 7 = -3 \text{ m/s}^2$  and  $a_x(5 \text{ s}) = 2(5) - 7 = 3 \text{ m/s}^2$

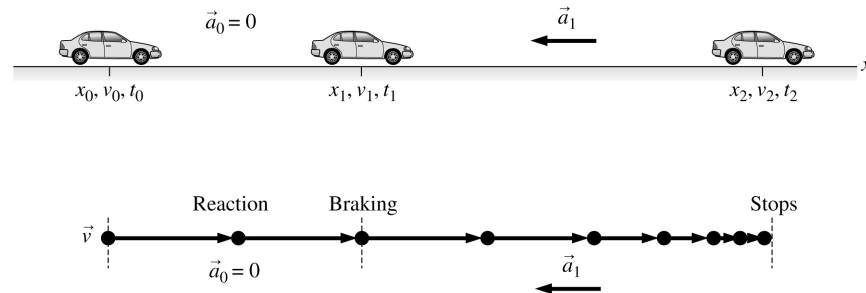
**Assess:** This problem does not have constant acceleration so the kinematic equations do not apply, but  $a = dv/dt$  always applies.

**2.48. Model:** The car is a particle and constant-acceleration kinematic equations hold.

**Visualize:**

<b>Known</b>	
$x_0 = 0$	$v_0 = 20 \text{ m/s}$
$t_0 = 0 \text{ s}$	$v_1 = 20 \text{ m/s}$
$t_1 = 0.50 \text{ s}$	$v_2 = 0$
$x_2 = 110 \text{ m}$	
<b>Find</b>	
$x_1$	$a_1$ $t_2$

**Pictorial representation**



**Solve:** This is a two-part problem. During the reaction time,

$$x_1 = x_0 + v_0(t_1 - t_0) + 1/2a_0(t_1 - t_0)^2$$

$$= 0 \text{ m} + (20 \text{ m/s})(0.50 \text{ s} - 0 \text{ s}) + 0 \text{ m} = 10 \text{ m}$$

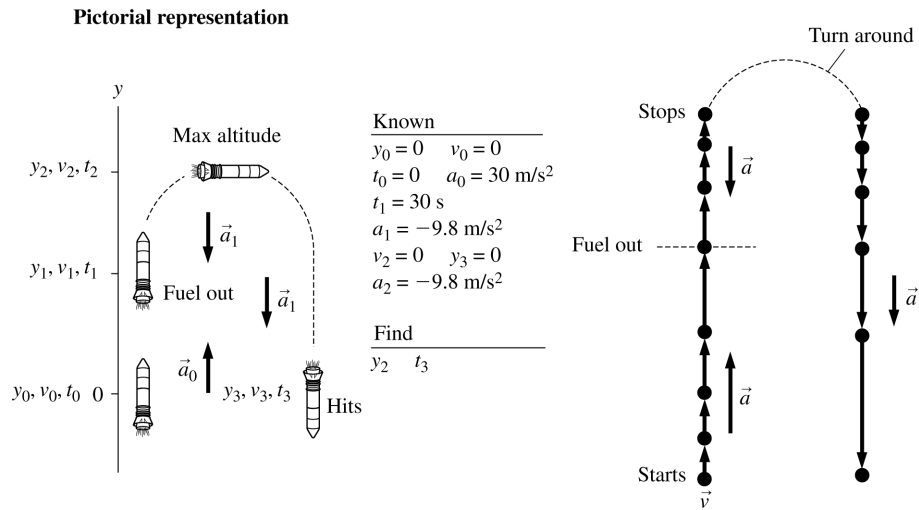
After reacting,  $x_2 - x_1 = 110 \text{ m} - 10 \text{ m} = 100 \text{ m}$ , that is, you are 100 m away from the intersection.

To stop successfully,

$$v_2^2 = v_1^2 + 2a_1(x_2 - x_1) \Rightarrow (0 \text{ m/s})^2 = (20 \text{ m/s})^2 + 2a_1(100 \text{ m}) \Rightarrow a_1 = -2 \text{ m/s}^2$$

**2.55. Model:** The rocket is represented as a particle.

**Visualize:**



**Solve: (a)** There are three parts to the motion. Both the second and third parts of the motion are free fall, with  $a = -g$ . The maximum altitude is  $y_2$ . In the acceleration phase:

$$y_1 = y_0 + v_0(t_1 - t_0) + \frac{1}{2}a(t_1 - t_0)^2 = \frac{1}{2}at_1^2 = \frac{1}{2}(30 \text{ m/s}^2)(30 \text{ s})^2 = 13,500 \text{ m}$$

$$v_1 = v_0 + a(t_1 - t_0) = at_1 = (30 \text{ m/s}^2)(30 \text{ s}) = 900 \text{ m/s}$$

In the coasting phase,

$$v_2^2 = 0 = v_1^2 - 2g(y_2 - y_1) \Rightarrow y_2 = y_1 + \frac{v_1^2}{2g} = 13,500 \text{ m} + \frac{(900 \text{ m/s})^2}{2(9.8 \text{ m/s}^2)} = 54,800 \text{ m} = 54.8 \text{ km}$$

The maximum altitude is 54.8 km ( $\approx 33$  miles).

**(b)** The rocket is in the air until time  $t_3$ . We already know  $t_1 = 30 \text{ s}$ . We can find  $t_2$  as follows:

$$v_2 = 0 \text{ m/s} = v_1 - g(t_2 - t_1) \Rightarrow t_2 = t_1 + \frac{v_1}{g} = 122 \text{ s}$$

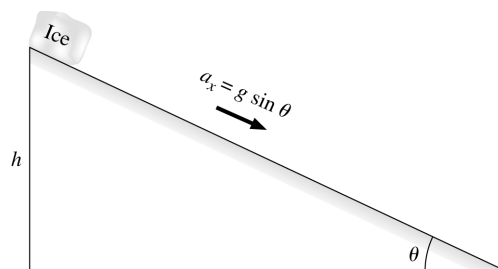
Then  $t_3$  is found by considering the time needed to fall 54,800 m:

$$y_3 = 0 \text{ m} = y_2 + v_2(t_3 - t_2) - \frac{1}{2}g(t_3 - t_2)^2 = y_2 - \frac{1}{2}g(t_3 - t_2)^2 \Rightarrow t_3 = t_2 + \sqrt{\frac{2y_2}{g}} = 228 \text{ s}$$

**Assess:** In reality, friction due to air resistance would prevent the rocket from reaching such high speeds as it falls, and the acceleration upward would not be constant because the mass changes as the fuel is burned, but that is a more complicated problem.

**2.63. Model:** Model the ice as a particle and use the kinematic equations for constant acceleration. Model the “very slippery block” and “smooth ramp” as frictionless. Set the  $x$ -axis parallel to the ramp.

**Visualize:**



Note that the distance down the ramp is  $\Delta x = h/\sin\theta$ . Also  $a_x = g \sin\theta$  down a frictionless ramp.

**Solve:** Use  $v_f^2 = v_i^2 + 2a_x\Delta x$ , where  $v_i = 0$ .

$$v_f^2 = 2a\Delta x \Rightarrow v_f = \sqrt{2(g \sin \theta) \frac{h}{\sin \theta}} = \sqrt{2gh}$$

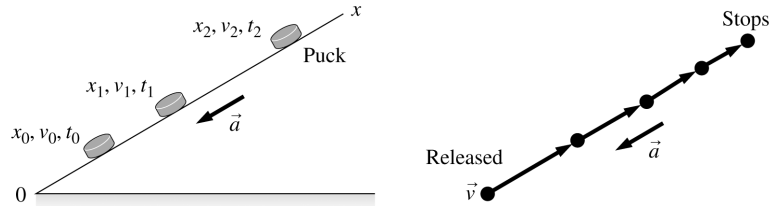
**Assess:** We will later learn how to solve this problem in an easier way with energy.

**2.65. Model:** We will use the particle model with constant-acceleration kinematic equations.

**Visualize:**

Known	
$x_0 = 0$	$t_0 = 0$
$v_0 = 5.0$ m/s	
$x_1 = 3.0$ m	
$v_1 = 4.0$ m/s	
$v_2 = 0$	
Find	
$x_2$	

**Pictorial representation**



**Solve:** The acceleration, being the same along the incline, can be found as

$$v_1^2 = v_0^2 + 2a(x_1 - x_0) \Rightarrow (4.0 \text{ m/s})^2 = (5.0 \text{ m/s})^2 + 2a(3.0 \text{ m} - 0 \text{ m}) \Rightarrow a = -1.5 \text{ m/s}^2$$

We can also find the total time the puck takes to come to a halt as

$$v_2 = v_0 + a(t_2 - t_0) \Rightarrow 0 \text{ m/s} = (5.0 \text{ m/s}) + (-1.5 \text{ m/s}^2)t_2 \Rightarrow t_2 = 3.3 \text{ s}$$

Using the above obtained values of  $a$  and  $t_2$ , we can find  $x_2$  as follows:

$$x_2 = x_0 + v_0(t_2 - t_0) + \frac{1}{2}a(t_2 - t_0)^2 = 0 \text{ m} + (5.0 \text{ m/s})(3.3 \text{ s}) + \frac{1}{2}(-1.5 \text{ m/s}^2)(3.3 \text{ s})^2 = 8.33 \text{ m}$$

That is, the puck goes through a displacement of 8.3 m. Since the end of the ramp is 8.5 m from the starting position  $x_0$  and the puck stops 0.17 m or 17 cm before the ramp ends, you are not a winner.