Free Fall Problems Worksheet

24 problems + 3 challenge
Answer key at the back

Name _____ Date _____ Period _____

Instructions. Take up as positive and measure height from the ground. Use g = 9.8 m/s² and neglect air resistance. Sketch the situation and mark the positive direction before you write an equation. Keep unrounded values between steps and give final answers to two significant figures.

Part A: dropped from a height ($v_0 = 0$). Part B: tossed down off a height (v_0 negative). Part C: thrown straight up (v_0 positive).

$v = v_0 - gt$	$y = y_0 + v_0 t - \frac{1}{2}gt^2$	$v^2 = v_0^2 - 2g(y - y_0)$	$a = -g = -9.8\ \text{m/s}^2$

Part A: Dropped from a height

Released from rest, so $v_0 = 0$.

1 A stone is dropped from rest off a bridge and hits the water 2.4 s later. Find the height of the bridge above the water and the stone's speed when it hits.

Answer: _____

2 A ball is dropped from rest from a height of 32 m. How long does it take to reach the ground, and how fast is it moving when it lands?

Answer: _____

3 A wrench slips off a scaffold 18.0 m above the ground. Find its height above the ground and its velocity 1.20 s after it starts to fall.

Answer: _____

4 Ball P is dropped from height H and lands after 1.5 s. Ball Q is dropped from height 4H. How long does Q take to land? Answer without finding H.

Answer: _____

5 Show that the distances a dropped object falls during its first, second, and third seconds are in the ratio 1 : 3 : 5.

Answer: _____

6 A rock dropped from rest hits the ground at 22 m/s. From what height was it dropped, and how long did it fall?

Answer: _____

7 A student drops a stone into a well and hears the splash 2.0 s later. Ignoring the time for the sound to travel, estimate the depth of the well. Is the true depth larger or smaller than your estimate? Explain.

Answer: _____

8 A ball is dropped from a height of 5.0 m. How long does it take to fall the last 1.0 m before it lands?

Answer: _____

Part B: Tossed down off a height

Thrown straight down, so v_0 is negative with up as positive.

9 A ball is thrown straight down at 5.0 m/s from a window 15 m above the ground. Find its speed when it lands and the time it takes.

Answer: _____

10 How much sooner does the ball in problem 9 land than a ball dropped from rest from the same window?

Answer: _____

11 A coin is thrown straight down from the top of a 40 m tower and lands 2.0 s later. Find the speed it was thrown with.

Answer: _____

12 A stone thrown straight down at 8.0 m/s hits the ground at 20 m/s. How high above the ground was it released, and how long was it in the air?

Answer: _____

13 A ball is thrown straight down at 3.0 m/s. Find its velocity and its distance below the release point 0.80 s later.

Answer: _____

14 A ball is thrown straight down at 10 m/s. What is its acceleration just after it leaves the hand? Is it larger than the acceleration of a dropped ball? Explain in one or two sentences.

Answer: _____

15 At the same instant, one ball is tossed horizontally at 6.0 m/s off a 12 m ledge and a second ball is dropped from the same ledge. Which lands first? How far from the base of the ledge does the tossed ball land?

Answer: _____

16 A ball is thrown straight down at 12 m/s from a 30 m cliff. Solve the position equation for the time to land, then use that time to find the velocity at impact. Check the velocity with $v^2 = v_0^2 - 2g(y - y_0)$.

Answer: _____

Part C: Thrown straight up

Thrown upward, so v_0 is positive. The acceleration is $-9.8\ m/s^2$ the whole time.

17 A ball is thrown straight up at 19.6 m/s from ground level. Find the time to reach the top, the maximum height, and the total time in the air.

Answer: _____

18 A ball is thrown straight up at 12 m/s. Find its velocity 0.50 s and 2.0 s after release, and say which way it is moving at each time.

Answer: _____

19 A ball is thrown straight up at 15 m/s. How fast is it moving when it is 8.0 m above the launch point, and at what two times is it there?

Answer: _____

20 A ball is thrown straight up at 9.0 m/s toward a shelf 5.0 m above the hand. Does it reach the shelf? Support your answer two ways.

Answer: _____

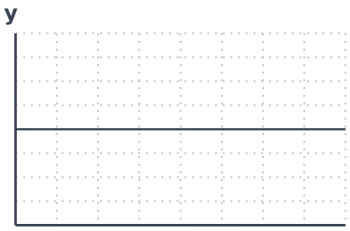
21 What launch speed gives a ball a maximum height of 3.2 m above the hand? How long does it take to reach that height?

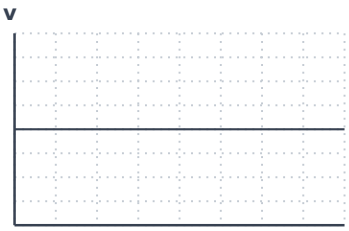
Answer: _____

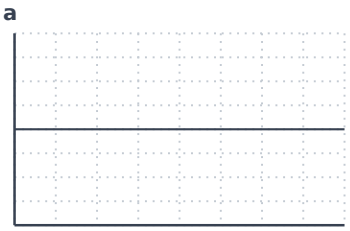
22 A ball is thrown straight up at 10 m/s from the edge of a roof 25 m above the ground, and on the way down it misses the roof. Find its maximum height above the ground, its total time in the air, and its speed when it lands.

Answer: _____

23 A ball is thrown straight up and caught at the same height. With up as positive, sketch its position, velocity, and acceleration against time. Which of the three is zero at the highest point?







Answer: _____

24 A ball thrown straight up passes a window ledge 6.0 m above the launch point 0.40 s after release, moving upward. Find the launch speed and the time when it passes the ledge again on the way down.

Answer: _____

Challenge set

Mixed problems. Some need two stages or two objects.

25 A ball is dropped from the top of a 30 m tower. At the same instant, a second ball is thrown straight up at 15 m/s from the ground directly below. When and at what height do they pass each other?

Answer: _____

26 A model rocket starts from rest and accelerates straight up at 12 m/s² for 2.5 s, then its engine shuts off. Find its maximum height and the total time from launch until it hits the ground. Neglect air resistance.

Answer: _____

27 A ball dropped from rest takes 0.12 s to pass a window 1.5 m tall. How far above the top of the window was it released?

Answer: _____

Answer Key

Up is positive, g = 9.8 m/s². Intermediate values are shown unrounded where they feed a later step. Guide, animations and reference sheet: burketutoringinfremont.com/ap-physics-1-free-fall-problems/

Part A: Dropped from a height

1. Height = ½gt² = 4.9(2.4)² = 28.2 m → **28 m**. Speed = gt = 9.8(2.4) = 23.5 m/s → **24 m/s**.
2. t = √(2h/g) = √(2(32)/9.8) = 2.56 s → **2.6 s**. Speed = gt = 9.8(2.556) = 25.0 m/s → **25 m/s**.
3. y = 18.0 − 4.9(1.20)² = 10.9 m → **11 m** above the ground. v = −9.8(1.20) = −11.8 m/s → **−12 m/s**, moving down.
4. **3.0 s**. Fall time is proportional to √h, and √4 = 2, so Q takes twice as long.
5. From $y = y_0 - \frac{1}{2}gt^2$, the object has fallen 4.9 m, 19.6 m, and 44.1 m after 1, 2, and 3 s. During each second it falls 4.9 m, 19.6 − 4.9 = 14.7 m, and 44.1 − 19.6 = 24.5 m. Dividing each by 4.9 gives **1 : 3 : 5**.
6. h = v²/(2g) = 22²/19.6 = 24.7 m → **25 m**. t = v/g = 22/9.8 = 2.24 s → **2.2 s**.
7. Depth ≈ ½gt² = 4.9(2.0)² = 19.6 m → **20 m**. The true depth is **smaller**. Part of the 2.0 s was the sound traveling back up, so the stone fell for less than 2.0 s.
8. Total fall time: √(2(5.0)/9.8) = 1.01015 s. Time to fall the first 4.0 m: √(2(4.0)/9.8) = 0.90351 s. The last 1.0 m takes 1.01015 − 0.90351 = 0.10664 s → **0.11 s**.

Part B: Tossed down off a height

9. v² = (−5.0)² − 2(9.8)(0 − 15) = 319, so the speed is 17.9 m/s → **18 m/s**. From $v = v_0 - gt$: −17.86 = −5.0 − 9.8t, so t = 1.31 s → **1.3 s**.
10. Thrown, from problem 9 before rounding: t = 1.31230 s. Dropped: t = √(2(15)/9.8) = 1.74964 s. Difference: 1.74964 − 1.31230 = 0.43734 s → **0.44 s** sooner.
11. $0 = 40 + v_0(2.0) - 4.9(2.0)^2$, so v_0 = −10.2 m/s. It was thrown down at **10 m/s**.
12. From $v^2 = v_0^2 - 2g(y - y_0)$: 20² = 8.0² + 2(9.8)h, so h = 17.1 m → **17 m**. From $v = v_0 - gt$: −20 = −8.0 − 9.8t, so t = 1.22 s → **1.2 s**.
13. v = −3.0 − 9.8(0.80) = −10.8 m/s → **−11 m/s**. Distance below release: 3.0(0.80) + 4.9(0.80)² = 5.54 m → **5.5 m**.
14. **−9.8 m/s²**, the same as a dropped ball. The throw sets the starting velocity. Once the ball leaves the hand, gravity is the only force on it, so its acceleration is g downward.
15. They **land at the same time**, because both start with zero vertical velocity from the same height: t = √(2(12)/9.8) = 1.56 s → 1.6 s. The tossed ball lands 6.0(1.565) = 9.39 m → **9.4 m** from the base.
16. $0 = 30 - 12t - 4.9t^2$. Quadratic formula: t = [−12 + √(144 + 588)]/9.8 = 1.54 s → **1.5 s** (the other root is negative). v = −12 − 9.8(1.536) = −27.1 m/s → **−27 m/s**. Check: √(12² + 2(9.8)(30)) = √732 = 27.1 m/s.

Part C: Thrown straight up

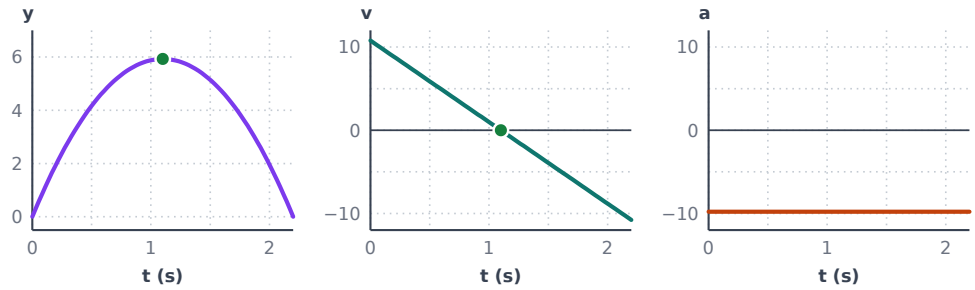
17. t_{top} = 19.6/9.8 = **2.0 s**. Maximum height = 19.6²/(2 × 9.8) = 19.6 m → **20 m**. Total time = 2(19.6)/9.8 = **4.0 s**.
18. v(0.50) = 12 − 9.8(0.50) = **+7.1 m/s**, moving up. v(2.0) = 12 − 9.8(2.0) = **−7.6 m/s**, moving down. It passed the top at 12/9.8 = 1.2 s.
19. v² = 15² − 2(9.8)(8.0) = 68.2, so the speed is **8.3 m/s**, moving up the first time and down the second. From $8.0 = 15t - 4.9t^2$: t = **0.69 s** and **2.4 s**.

20 **No.** Maximum rise = $9.0^2/(2 \times 9.8) = 4.1$ m, which is less than 5.0 m. Second way: $5.0 = 9.0t - 4.9t^2$ rearranges to $4.9t^2 - 9.0t + 5.0 = 0$, whose discriminant is $81 - 98 = -17$. A negative discriminant means there is no real time, so the ball does not reach 5.0 m.

21 At the top $v = 0$: $0 = v_0^2 - 2(9.8)(3.2)$, so $v_0 = 7.92$ m/s → **7.9 m/s**. Time: $7.92/9.8 =$ **0.81 s**.

22 Maximum height above the ground: $25 + 10^2/(2 \times 9.8) = 30.1$ m → **30 m**. Landing: $0 = 25 + 10t - 4.9t^2$, so $t = [10 + \sqrt{(100 + 490)}]/9.8 = 3.50$ s → **3.5 s**. Speed: $\sqrt{(10^2 + 2(9.8)(25))} = 24.3$ m/s → **24 m/s**.

23 Position: a downward-opening parabola that starts and ends at the launch height, with its peak at the middle time. Velocity: a straight line with slope -9.8 m/s², from $+v_0$ down through zero at the middle time to $-v_0$. Acceleration: a horizontal line at -9.8 m/s². At the top, **only the velocity is zero**.



24 $6.0 = v_0(0.40) - 4.9(0.40)^2$, so $v_0 = 16.96$ m/s → **17 m/s**. The two times at the same height are symmetric about $t_{top} = v_0/g = 1.73$ s, so they add to $2v_0/g = 3.46$ s. Second pass: $3.46 - 0.40 = 3.06$ s → **3.1 s**.

Challenge set

25 $y_1 = 30 - 4.9t^2$ and $y_2 = 15t - 4.9t^2$. Setting them equal, the $-4.9t^2$ terms cancel: $30 = 15t$, so $t =$ **2.0 s**. Height: $30 - 4.9(2.0)^2 = 10.4$ m → **10 m**. At that moment ball 2 is already moving down at 4.6 m/s, and ball 1 has not landed yet (it lands at 2.5 s).

26 Engine stage (not free fall): $v = 12(2.5) = 30$ m/s and $y = \frac{1}{2}(12)(2.5)^2 = 37.5$ m. Free fall from engine shutoff: rise = $30^2/(2 \times 9.8) = 45.9$ m, so the maximum height is 83.4 m → **83 m**. Time up after shutoff: $30/9.8 = 3.06$ s. Fall from 83.4 m: $\sqrt{(2(83.4)/9.8)} = 4.13$ s. Total: $2.5 + 3.06 + 4.13 = 9.69$ s → **9.7 s**.

27 Across the window $\Delta y = -1.5$ m in 0.12 s: $-1.5 = v(0.12) - 4.9(0.12)^2$, so the velocity at the top of the window is $v = -11.912$ m/s. A dropped ball reaches that speed after falling $v^2/(2g) = 11.912^2/19.6 = 7.2396$ m → **7.2 m**.

Written by Berke Sahbazoglu, Burke Tutoring In Fremont · (510) 453-0350 · Free to print and use in class. A link back to burketutoringinfremont.com/ap-physics-1-free-fall-problems/ is appreciated.