Free Fall and Vertical Motion at Earth's Surface

Free fall describes the situation in which the only force acting on a falling object is gravity. In other words, a situation in which air resistance can be ignored. In such an idealized situation, all objects will have the same constant rate of acceleration:

$$g = 9.8 \ m/s^2 \ [down]$$

Solving Free Fall Problems

Problems involving freely falling bodies can be solved using the equations for constant acceleration:

$$d = \left(\frac{v_f + v_i}{2}\right) \cdot t \qquad\qquad v_f = v_i + at$$

$$d = v_i t + \frac{1}{2}at^2 \qquad\qquad v_f^2 = v_i^2 + 2ad$$

where the acceleration a is equal to the acceleration due to gravity g.

Example 1 Dropping an Object.
Suppose that a ball is dropped from a tower $70.0 \ m$ high. How far will the ball have fallen after a time $t = 3.00 \ s$?

Example 2 Throwing an Object Downwards.
Suppose you were in the observation deck of the CN Tower at a height of $342\ m$, and you threw a marble straight downwards with a velocity of $35.0\ m/s$. Assume there is no air resistance.

    a) Determine the velocity of the marble just before it strikes the ground.

    b) Determine the time it takes for the marble to reach the ground.

Example 3 Throwing an Object Upwards.
If you threw a ball straight upwards with a velocity of $25.0 \; m/s$,

    a) how long will it take to reach its maximum height?

    b) how high would it go?

    c) how long would it take to return to your hand?

Free Fall Worksheet

1. From the top of a cliff, a person uses a slingshot to fire a pebble straight downward, which is the negative direction. The initial downward velocity of the pebble is $9.0\ m/s$.
   a) What is the acceleration (magnitude and direction) of the pebble during the downward motion? (-9.8 m/s^2 or 9.8 m/s^2 [down])
   b) Is the pebble decelerating? Explain.
   c) After $0.50\ s$, how far beneath the cliff-top is the pebble? ($-5.725\ m$)

2. The greatest height reported for a jump into an airbag is $99.4\ m$ by stunt-man Dan Koko. In 1984 he jumped from rest from the top of the Vegas World Hotel and Casino. He struck the airbag at a speed of $39\ m/s$. To assess the effects of air resistance, determine how fast he would have been traveling on impact had there been no air resistance. ($-44.1\ m/s$)

3. An arrow is fired from ground level straight upward with an initial velocity of $15\ m/s\ \left[up\right]$. How long is the arrow in the air before it strikes the ground? ($3.06\ s$)

4. A golf ball rebounds from the floor and travels straight upward with a speed of $5.0\ m/s$. To what maximum height does the ball rise? ($1.28\ m$)

5. From her bedroom window a girl drops a water-filled balloon to the ground, $6.0\ m$ below. If the balloon is released from rest, how long is it in the air? ($1.11\ s$)

6. Suppose a ball is thrown vertically upward. Eight seconds later it returns to its point of release. What is the initial velocity of the ball? ($39.2\ m/s\ \left[up\right]$)

7. A diver springs upward with an initial speed of $1.8\ m/s$ from a $3.0\ m$ board.
   a) Find the velocity with which he strikes the water. (**Hint**: When the diver reaches the water, his displacement is $-3.0\ m$, assuming that down is the negative direction). ($-7.88\ m/s$)
   b) What is the highest point he reaches above the water? ($3.165\ m$)

8. A ball is thrown straight upward and rises to a maximum height of $16\ m$ above its launch point. At what height above its launch point has the speed of the ball decreased to one-half of its initial value? ($12\ m$)

9. Two identical pellet guns are fired simultaneously from the edge of a cliff. These guns impart an initial speed of $30\ m/s$ to each pellet. Gun A is fired straight upward, with the pellet going up and then falling back down, eventually hitting the ground beneath the cliff. Gun B is fired straight downward. In the absence of air resistance, how long after pellet B hits the ground does pellet A hit the ground? ($6.12\ s$)