Physics I: Mechanics
Freefall—Motion with Constant Acceleration

Problem:

2–38 A hot-air balloonist, rising vertically with a constant velocity of magnitude 5.00 m/s, releases a sandbag at an instant when the balloon is 40.0 m above the ground (Fig. 2–32). After it is released, the sandbag is in free fall. a) Compute the position and velocity of the sandbag at 0.250 s and 1.00 s after its release. b) How many seconds after its release will the bag strike the ground? c) With what magnitude of velocity does it strike? d) What is the greatest height above the ground that the sandbag reaches? e) Sketch *a-t*, *v-t*, and *y-t* graphs for the motion.

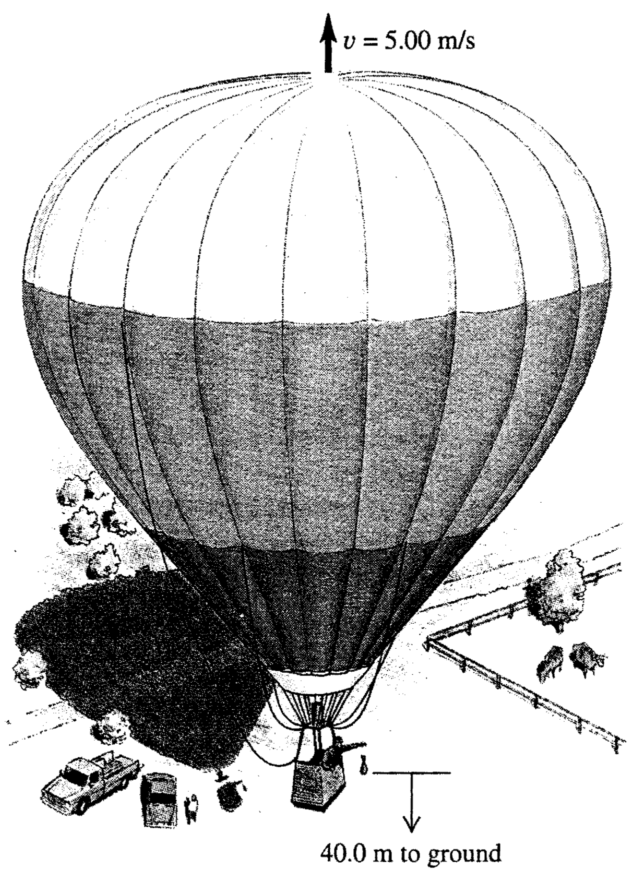


FIGURE 2–32 Exercise 2–38.

Problem: A hot-air balloonist, rising vertically with a constant velocity of magnitude 5.00 m/s, releases a sandbag at an instant when the balloon is 40.0 m above the ground. After it is released, the sandbag is in free fall. (b) How many seconds after its release will the bag strike the ground? (d) What is the greatest height above the ground that the sandbag reaches?

The key idea here is to recognize that this is a freefall problem, but the sandbag starts out with the same initial velocity as the balloon.

$$y_i = 40.0\,\mathrm{m}$$
$$v_i = 5.0\,\mathrm{m/s}$$
$$a = -g = -9.8\,\mathrm{m/s^2}$$

To "strike the ground" means that $y_f = 0$.

$$y_f = y_i + v_i t + \frac{1}{2} a t^2$$
$$0 = 40\,\mathrm{m} + (5.0\,\mathrm{m/s})t - \frac{1}{2}(9.8\,\mathrm{m/s^2})t^2$$

Rearranging and solving for t, we get a quadratic. The units will be in seconds.

$$4.9t^2 - 5.0t - 40 = 0$$

There are two solutions: $t = -2.39\,\mathrm{s}$ and $t = 3.41\,\mathrm{s}$. Since the sandbag hits the ground *after* it is released, pick the positive time.

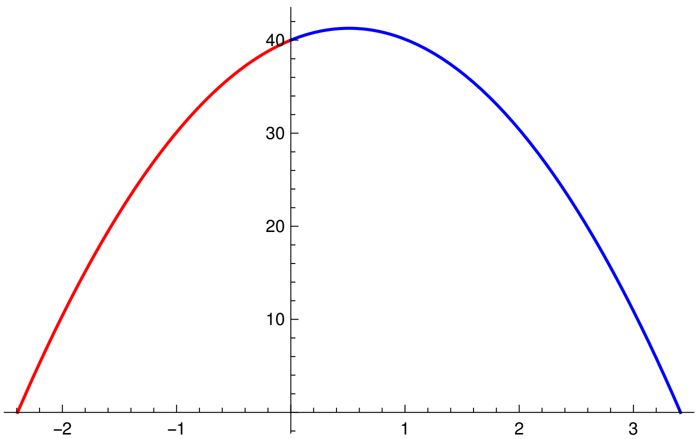
To find the maximum height, solve for $v_f = 0$. It is simplest to use the velocity squared equation, which does not involve time.

$$
\begin{aligned}
v_f^2 &= v_i^2 + 2a(y_f - y_i) \\
v_f^2 - v_i^2 &= 2a(y_f - y_i) \\
\frac{v_f^2 - v_i^2}{2a} &= (y_f - y_i) \\
\frac{v_f^2 - v_i^2}{2a} + y_i &= y_f \\
y_f &= \frac{v_f^2 - v_i^2}{2a} + y_i \\
y_f &= \frac{0\,\mathrm{m^2/s^2} - 25.0\,\mathrm{m^2/s^2}}{2(-9.8\,\mathrm{m/s^2})} + 40.0\,\mathrm{m} \\
y_f &= 41.3\,\mathrm{m}
\end{aligned}
$$

Phys 111: Freefall problem -- The Rising Balloon

```
In[1]:= y0 = 40; v0 = 5; g = 9.8; a = -g;

In[2]:= v[t_] := v0 + a t
        y[t_] := y0 + v0 t + (1 / 2) a t^2

In[4]:= parta = Solve[y[t] == 0, t]

Out[4]= {{t → -2.39214}, {t → 3.41254}}

In[9]:= before = t /. parta[[1]];
        after = t /. parta[[2]];

In[15]:= Show[{
           Plot[y[t], {t, before, 0}, PlotStyle → Red],
           Plot[y[t], {t, 0, after}, PlotStyle → Blue]}, PlotRange → All]
```

Out[15]=

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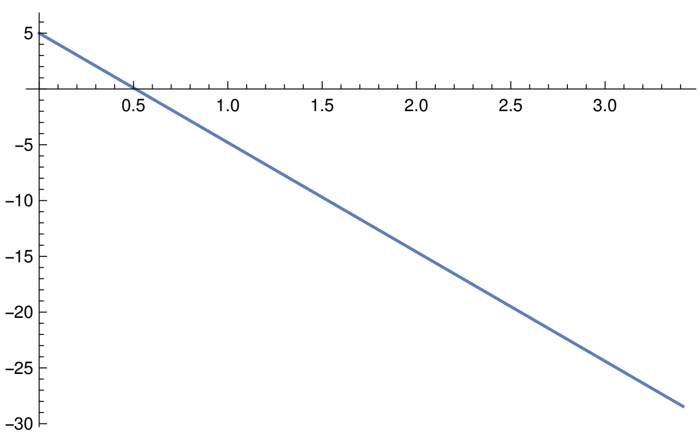
In[16]:= Plot[v[t], {t, 0, after}]
```

Out[16]=

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In[17]:= FindMaximum[y[t], t]

Out[17]= {41.2755, {t → 0.510204}}
```