Free Fall Problems

1. If air resistance is negligible, free fall considerations may be used to determine heights of structures, cliffs, etc., where direct measurement is often not feasible. Calculate the height of a bridge if a rock dropped over the edge takes 1 second to hit the water.

$v_i = 0$

$d = ?$

$a = -9.8\ m/s^2$

$t = 1\ s$

$d = v_i t + \frac{1}{2} a t^2$

$= \frac{1}{2}(-9.8)(1)^2$

$d = -4.9$

the bridge is 4.9 m high

2. What is the height of a flagpole if a ball thrown from the ground to the top of the flagpole returns to the ground in 4 seconds?

$v_i = 0$

$d = ?$

$a = -9.8\ m/s^2$

$t = 2s$ (it would take half the time to arrive at the top)

$d = v_i t + \frac{1}{2} a t^2$

$= \frac{1}{2}(-9.8)(2)^2$

$= -19.6\ m$

the flag pole is 19.6 m high

3. Batman, in the spirit of scientific curiosity consistent with his work in the bat cave, determines to test the law of gravity for himself. He walks off a Gotham City skyscraper 300 m high, stopwatch in hand, and starts his free fall. Robin, the Boy Wonder, notices that the Joker (that evil fellow!) has unfastened the Batrope, which was to have saved Batman from crashing to death by jerking him to a stop just before hitting the pavement. Clark Kent, strolling on the roof, notices the situation, and 5 seconds after Batman leaves the roof, Superman arrives at the scene and dives off the roof to save Batman. Superman can accelerate at whatever rate he wants as long as his initial velocity is zero. Calculate the acceleration Superman needs to catch Batman just before Batman reaches the ground?

Batman

$v_i = 0$

$a = -9.8\ m/s^2$

$d = -300\ m$

$t = ?$

$d = v_i t + \frac{1}{2} a t^2$

$-300 = \frac{1}{2}(-9.8) t^2$

$t = 7.82\ s$

Superman

$v_i = 0$

$a = ?$

$d = -300$

$t = 7.82 - 5 = 2.82$

$d = v_i t + \frac{1}{2} a t^2$

$-300 = \frac{1}{2} a (2.82)^2$

$a = 75.4\ m/s^2$

4. A juggler performs in a room whose ceiling is 3.0 m above the level of her hands. She throws a ball vertically upward so that it just reaches the ceiling.

(a) With what initial velocity does she throw the ball?

$v_i = ?$

$v_f = 0$

$d = 3.0\ m$

$a = -9.8\ m/s^2$

$v_f^2 = v_i^2 + 2ad$

$0 = v_i^2 + 2(-9.8)(3)$

$v_i = 7.7\ m/s$

(b) What time is required for the ball to reach the ceiling?

$v_f = 0$

$d = 3.0\ m$

$a = -9.8\ m/s^2$

$v_i = 7.7\ m/s$

$v_f = v_i + at$

$0 = 7.7 + (-9.8) t$

$t = 0.79\ s$