Conceptual Questions

1. Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. The time it takes the balls to reach the ground below will be:
   a) about half as long for the heavier ball as for the lighter one.
   b) about half as long for the lighter ball as for the heavier one.
   c) about the same for both balls.
   d) considerably less for the heavier ball, but not necessarily half as long.
   e) considerably less for the lighter ball, but not necessarily half as long.

2. An Olympic diver does a triple somersault off the 10 m tower. She left the tower with a speed of 4 m/s and entered the water in the vertical position. What was her acceleration just before she hit the water?
   a) the acceleration due to gravity, "g"
   b) slightly more than the acceleration due to gravity
   c) slightly less than the acceleration due to gravity
   d) zero
   e) cannot be determined unless the direction of her velocity is given

3. A rock was filmed as it fell from rest. Analysis showed an acceleration of 9.8 m/s^2 [down]. Suppose the film were run backwards, at the same frame rate. What would the apparent acceleration of the rock be now?
   a) 9.8 m/s^2 [down] b) 9.8 m/s^2 [up] c) 0 m/s^2
   d) none of these e) indeterminate

4. A stone is dropped from the top of a tower of height h meters. It takes t seconds for the stone to reach the ground. Where is the stone at time 0.50t?
   a) The stone is 0.25h m from the ground.
   b) The stone is 0.5h m from the ground.
   c) The stone is 0.75h m from the ground.
   d) The position of the stone depends on its mass.
   e) The position of the stone depends on its density.
5. A baseball player hits a foul ball straight up into the air, leaving the bat with a speed of 120 km/h. It later strikes the catcher's glove with the same speed as when it was first hit (the ball is caught at the same height it was hit at and air resistance has been neglected). Explain why this has happened.

   Due to the symmetry of the example, the upwards motion to maximum height mirrors the downwards motion from maximum height to the original position. Since the time of motion and the acceleration is the same in both cases, the velocities will change by the same amount: from velocity, ***v***, to rest moving up and from rest to the same velocity, ***v***, coming down again.

Problems

6. In order to reach a height of 101 m in the air, what initial velocity must an object have?

$\Delta\vec{d} = 101\ m\ [up]$
$\vec{a} = -9.8\ m/s^2\ [up]$
$\vec{v}_2 = 0\ m/s\ [up]$
$\vec{v}_1 = ?$

$v_2^2 = v_1^2 + 2a\Delta d$
$v_1 = (v_2^2 - a\Delta d)^{1/2}$
$v_1 = \left((0\ m/s)^2 - (-9.8\ m/s^2)\ (101\ m)\right)^{1/2}$
$v_1 = 44.49\ m/s$
$\vec{v}_1 = 44\ m/s\ [up]$

7. A soccer ball is kicked straight up at a speed of 3.0×10^1 m/s. How long will it take to reach a height of 5.0 m?

$\Delta\vec{d} = 5.0\ m\ [up]$
$\vec{a} = -9.8\ m/s^2\ [up]$
$\vec{v}_1 = 3.0 \times 10^1\ m/s\ [up]$
$\Delta t = ?$

$\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$
$\frac{1}{2}\vec{a}\Delta t^2 + \vec{v}_1\Delta t - \Delta\vec{d} = 0$ (quadratic)
$\frac{1}{2}(-9.8\ m/s^2)\Delta t^2 + (3.0 \times 10^1\ m/s)\Delta t - 5.0\ m = 0$
$t_1 = 0.171\ s$
$t_2 = 5.95\ s$

It will take 0.17 s to reach 5 m for the first time (going upwards). It will reach a height of 5.0 m a second time on the way down after 5.95 s).

8. Determine the average speed of an apple that starts from rest and falls freely for 3.00 s.

$\Delta t = 3.00\ s$
$\vec{a} = -9.80\ m/s^2\ [up]$
$\vec{v}_1 = 0\ m/s\ [up]$
$\Delta\vec{d} = ?$

$\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$
$\Delta\vec{d} = (0\ m/s)(3.00\ s) + \frac{1}{2}(-9.80\ m/s^2)(3.00\ m/s)^2$
$\Delta\vec{d} = 44.1\ m\ [down]$

$v = \frac{d}{t}$
$v = \frac{44.1m}{3.00\ s}$
$v = 14.7\ m/s$

9. A stone is dropped by a girl from the top of a cliff and it hits the water below. If the sound of the splash reaches the girl 3.0 s after she drops the stone, calculate the distance from the top of the cliff to the water surface. The speed of sound this day is 340 m/s.

Stone

$\vec{v}_1 = 0\ m/s\ [up]$
$\vec{a} = -9.8\ m/s^2\ [up]$
$\Delta\vec{d} = ?$
$\Delta t = ?$

$\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$

Sound

$\vec{a} = 0\ m/s^2\ [up]$
$\vec{v} = 340\ m/s\ [up]$
$\Delta\vec{d} = ?$
$\Delta t = ?$

$\Delta\vec{d} = \vec{v}\Delta t$

$\Delta\vec{d}_{stone} = -\Delta\vec{d}_{sound}$
$\Delta t_{stone} + \Delta t_{sound} = 3.0\ s$

$-\vec{v}_{sound}\Delta t_{sound} = \frac{1}{2}\vec{a}\Delta t_{stone}^2$
$-\vec{v}_{sound}(3.0\ s - \Delta t_{stone}) = \frac{1}{2}\vec{a}\Delta t_{stone}^2$
$\frac{1}{2}(-9.8\ m/s^2\ [up])\Delta t_{stone}^2 = -(340\ m/s\ [up])(3.0\ s - \Delta t_{stone})$
$(-4.9\ )\Delta t_{stone}^2 - (340\ )\Delta t_{stone} + 1020 = 0$ (quadratic)
$\Delta t_{stone1} = -72.3\ s$ (rejected)
$\Delta t_{stone2} = 2.88\ s$

$\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$
$\Delta\vec{d} = \frac{1}{2}(-9.8\ m/s^2\ [up])(2.88\ s)^2$
$\Delta\vec{d} = -40.64\ m\ [up]$

$distance = 41\ m$

10. An astronaut tossed a ball vertically upwards on the moon. It reached a height of 85 m before landing back in her hand 20 s after leaving it. You may ignore air resistance in this question. If the same ball were thrown upward on Earth with the same initial speed as on the moon, how long would it be in flight for?

Moon:

$\Delta\vec{d} = 85\ m\ [up]$	$\Delta\vec{d} = \frac{1}{2}(\vec{v}_1 + \vec{v}_2)\Delta t$
$\Delta t = 20\ s\ \div 2 = 10\ s$	$\vec{v}_1 = \frac{2\Delta\vec{d}}{\Delta t} - \vec{v}_2$
$\vec{v}_2 = 0\ m/s\ [up]$	$\vec{v}_1 = \frac{2(85\ m\ [up])}{10\ s} - 0\ m/s$
$\vec{v}_1 = ?$	$\vec{v}_1 = 17\ m/s\ [up]$

Earth:

$\vec{a} = -9.8\ m/s^2\ [up]$	$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$
$\vec{v}_1 = 17\ m/s\ [up]$	$\Delta t = \frac{\vec{v}_2 - \vec{v}_1}{\vec{a}}$
$\vec{v}_2 = 0\ m/s\ [up]$	$\Delta t = \frac{0\ m/s\ [up] - 17\ m/s\ [up]}{-9.8\ m/s^2\ [up]}$
$\Delta t = ?$	$\Delta t = 1.734\ s$

Total time $1.734\ s \times 2 = 3.5\ s$

11. A boy is sitting in his tree house and observes a falling walnut passing from the top to the bottom of his window. The window is 2.5 m tall and it takes 0.43 s for the walnut to pass the window. How far is the top of the window from the squirrel above it that dropped the walnut? Ignore air resistance.

Passing window

$\Delta\vec{d} = 2.5\ m\ [down]$	$\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$
$\vec{a} = -9.8\ m/s^2\ [up]$	$\vec{v}_1 = \frac{\Delta\vec{d} - \frac{1}{2}\vec{a}\Delta t^2}{\Delta t}$
$\Delta t = 0.43\ s$	$\vec{v}_1 = \frac{-2.5\ m\ [up] - \frac{1}{2}(-9.8\ m/s^2\ [up])(0.43\ s)^2}{0.43\ s}$
$\vec{v}_1 = ?$	$\vec{v}_1 = -3.71\ m/s\ [up]$

Above window

$\vec{v}_1 = 0\ m/s\ [up]$

$\vec{a} = -9.8\ m/s^2\ [up]$

$\vec{v}_2 = -3.71\ m/s\ [up]$

$\Delta\vec{d} = ?$

$v_2^2 = v_1^2 + 2a\Delta d$

$\Delta d = \frac{v_2^2 - v_1^2}{2a}$

$\Delta d = \frac{(-3.71\ m/s)^2 - (0\ m/s)^2}{2(-9.8\ m/s^2)}$

$\Delta d = 0.70\ m$

12. A stone is thrown vertically upward with a speed of 12.0 m/s from the edge of a cliff 70.0 m high.
    a) How much later does it reach the bottom of the cliff?

$\Delta\vec{d} = -70.0\ m\ [up]$

$\vec{a} = -9.80\ m/s^2\ [up]$

$\vec{v}_1 = 12.0\ m/s\ [up]$

$\Delta t = ?$

$\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$

$\frac{1}{2}\vec{a}\Delta t^2 + \vec{v}_1\Delta t - \Delta\vec{d} = 0$

$\frac{1}{2}(-9.8\ m/s^2)\Delta t^2 + (12.0\ m/s)\Delta t - (-70.0\ m) = 0$

$\Delta t_1 = -2.75\ s$ (rejected)

$\Delta t_2 = 5.20\ s$

    b) What is its speed just before hitting the bottom of the cliff?

$\Delta\vec{d} = -70.0\ m\ [up]$

$\vec{a} = -9.80\ m/s^2\ [up]$

$\vec{v}_1 = 12.0\ m/s\ [up]$

$\vec{v}_2 = ?$

$v_2^2 = v_1^2 + 2a\Delta d$

$v_2 = \sqrt{v_1^2 + 2a\Delta d}$

$v_2 = \sqrt{(12.0\ m/s)^2 + 2(-9.8\ m/s^2)(-70.0\ m)}$

$v_2 = 38.9\ m/s$

    c) What total distance did it travel?

$\vec{v}_1 = 12.0\ m/s\ [up]$

$\vec{a} = -9.80\ m/s^2\ [up]$

$\vec{v}_2 = 0\ m/s\ [up]$

$\Delta\vec{d} = ?$

$v_2^2 = v_1^2 + 2a\Delta d$

$\Delta d = \frac{v_2^2 - v_1^2}{2a}$

$\Delta d = \frac{(0\ m/s)^2 - (12.0\ m/s)^2}{2(-9.8\ m/s^2)}$

$\Delta d = 7.35\ m$ to reach maximum height

$\text{Total distance} = 2(7.35\ m) + 70.0\ m = 84.7\ m$