Section 2.7: Free Fall and Acceleration Due to Gravity

Remember:

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

Any time you are working with objects moving freely through the air, they will always be accelerated downward at the rate of 9.81 m/s^2! It will not usually be stated – you will need to recognize the situation and realize that a = -9.81 m/s^2 as an unstated given!

- Displacement is positive if it finishes above its initial position; if it finishes below its initial position, its displacement is negative.

Examples

1. A ball takes 2.00 s to reach the water when dropped from bridge. Calculate the displacement of the ball.

$V_1 = 0$

$t = 2.00\ s$
$V_1 = 0\ m/s$
$a = -9.8\ m/s^2$
$d = ?$

$d = V_1 t + \frac{1}{2} a t^2$
$d = \frac{1}{2}(-9.8\ m/s^2)(2.00\ s)^2$
$d = -19.6\ m$

2. An 8.0 kg object is dropped from a height of 6.5 m above the ground. What is the object's velocity after 0.75 s?

~~$m = 8.0\ kg$~~
~~$d = -6.5\ m$~~
$V_1 = 0$
$V_2 = ?$
$a = -9.8\ m/s^2$
$t = 0.75\ s$

$a = \frac{V_2 - V_1}{t}$
$V_2 - V_1 = at$
$V_2 = V_1 + at$
$V_2 = (-9.8\ m/s^2)(0.75\ s)$
$V_2 = -7.4\ m/s$

3. An athlete in good physical condition can land on the ground at a speed of up to 12 m/s without injury. Calculate the maximum height from which he/she can jump without injury.

$V_1 = 0\ m/s$

$d = ?$

$V_2 = -12\ m/s$

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

$$d = \frac{V_2^2 - V_1^2}{2a}$$

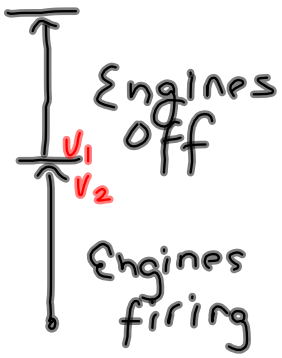
$$d = \frac{(-12\ m/s)^2}{2(-9.8\ m/s^2)}$$

$$d = -7.3\ m$$

So He can jump from a height of 7.3m.

4. A rocket is launched from rest with a uniform vertical acceleration of 15.0 m/s^2. After 4.80 s, the engines shut off.

A) To what height has the rocket risen in 4.80 s?



Firing

$V_1 = 0$

$a = 15.0\ m/s^2$

$t = 4.80\ s$

(a) $d = ?$

(B) Off

$V_1 = ?$

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

$V_2 = 0$

(b) $d = ?$

$V_2 = ?$

$$d = V_1 t + \frac{1}{2} a t^2$$

$$= \frac{1}{2}(15\ m/s^2)(4.80\ s)^2$$

$$d = 173\ m$$

B) How much higher will the rocket rise after the engines shut off? (max height)

1. find V_2 from part 1 → This is V_1 in part 2.

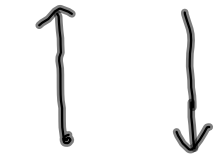
$V_2 = V_1 + at$

$V_2 = (15\,m/s^2)(4.80s) = 72\,m/s$

$d = \frac{V_2^2 - V_1^2}{2a} = \frac{0 - (72\,m/s)^2}{2(-9.8\,m/s^2)} = 264m$

5. An object is thrown up into the air with a speed of 18 m/s.

A) How long will it take the ball to return to the same position?



$V_1 = 18\,m/s$

$t = ?$

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

$V_2 = -18\,m/s$

$t = \frac{V_2 - V_1}{a} = \frac{-18\,m/s - 18\,m/s}{-9.8\,m/s^2}$

$t = 3.7s$

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or $V_1 = 18\,m/s$

$V_2 = 0\,m/s$ (at max height)

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

$t_{up} = ?$

$t_{up} = \frac{V_2 - V_1}{a} = \frac{0 - 18\,m/s}{-9.8\,m/s^2}$

$t_{up} = 1.85s$

$t_T = 2 \times 1.85s = 3.7s$

B) What is the maximum height the ball will reach?

$V_2 = 0$

$d = ?$
$V_1 = 18\ m/s$
$a = -9.8\ m/s^2$
$V_2 = 0$

$$d = \frac{V_2^2 - V_1^2}{2a}$$

$$d = \frac{0 - (18\ m/s)^2}{2(-9.8\ m/s^2)}$$

$$d = 17\ m$$

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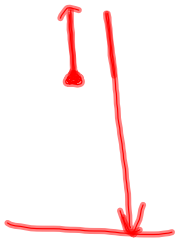
6. A ball is dropped from a helicopter from a height of 50.0 m. When the ball was dropped, the helicopter was moving upward with a velocity of 30.0 m/s. How long would it take the object to hit the ground?



$V_1 = 30.0\ m/s$
$a = -9.8\ m/s^2$
$*\vec{d} = -50\ m$
$t = ?$
$*$ Find V_2 first

$d = V_1 t + \frac{1}{2}at^2$
do not use b/c V_1 is not 0.

$$V_2^2 = V_1^2 + 2ad$$

$$V_2^2 = (30\ m/s)^2 + 2(-9.8\ m/s^2)(-50\ m)$$

$$V_2^2 = 1880\ m^2/s$$

$*\ V_2 = 43...\ m/s$

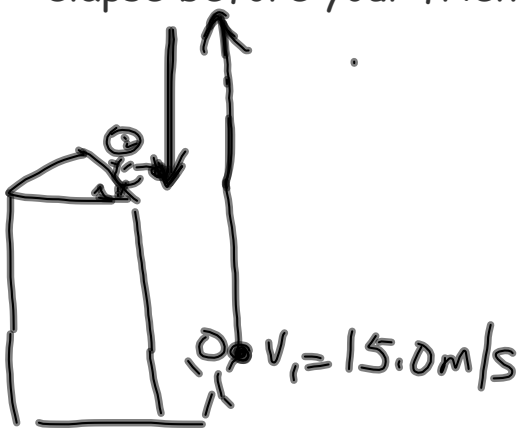
$V_2 = 43.4\ m/s$ (b/c object is falling)

$$t = \frac{V_2 - V_1}{a}$$

$$= \frac{+43.4\ m/s - 30\ m/s}{-9.8\ m/s^2}$$

$= 7.5\ s$ 1.4s

7. Your friend is sitting on the roof of your house 6.0 m above your throwing arm as you stand on the ground. You toss a ball upward which bypasses your friend on the way up, but which he catches on the way down. If the ball leaves your hand at 15.0 m/s, how many seconds elapse before your friend catches it?



$V_1 = 15\ m/s$

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

$d = 6.0\ m$

$t = ?$

$V_2 = ?$

$$V_2^2 = V_1^2 + 2ad$$

$$V_2^2 = (15\ m/s)^2 + 2(-9.8\ m/s^2)(6.0\ m)$$

$$V_2^2 = 107.4\ m^2/s^2$$

$$V_2 = \pm\sqrt{107.4\ m^2/s^2}$$

$V_2 = -10.36\ m/s$ (– b/c he caught it on the way down)

$$t = \frac{V_2 - V_1}{a} = \frac{-10.36\ m/s - 15\ m/s}{-9}$$

$$= +2.65$$