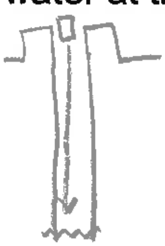
Free Fall

In the absence of air resistance... all objects accelerate at the same rate

Near Earth's surface this acceleration is: $9.8\ m/s^2$ [down]
* most often $-9.8 m/s^2$ as up is usually + ve direction *

An object that is only moving under the influence of gravity is said to be in a state of:
FREE FALL

Example: A student drops their homework down a wishing well. After 2.4 s it hits the water at the bottom. How deep is the well?

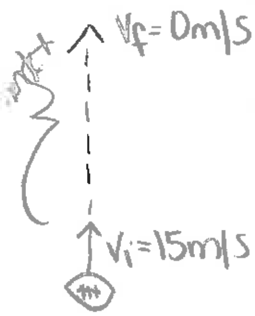


Given: $v_i = 0 m/s$
$a = -9.8 m/s^2$
$t = 2.4 s$

Need: $d = ?$

$d = v_i t + \frac{1}{2} a t^2$
$= \frac{1}{2} a t^2$
$= \frac{1}{2}(-9.8 m/s^2)(2.4 s)^2$
$= -28 m$

Example: A football is kicked straight up in the air at 15 m/s.
a. How high does it go?



Given: $v_i = 15 m/s$
$a = -9.8 m/s^2$
$v_f = 0 m/s$

Need: d

$v_f^2 = v_i^2 + 2ad$
$v_f^2 - v_i^2 = 2ad$
$d = \frac{v_f^2 - v_i^2}{2a}$
$= \frac{0^2 - 15 m/s^2}{2(-9.8 m/s^2)}$
$= 11.48 m = 11 m$

Moral of the story
On level ground:
→ time up = time down
→ $v_f = -v_i$

b. What is its total hangtime?

1st half

$a = \frac{v_f - v_i}{t}$
$t = \frac{v_f - v_i}{a}$
$= \frac{0 - 15 m/s}{-9.8 m/s^2}$
$= 1.531 s$

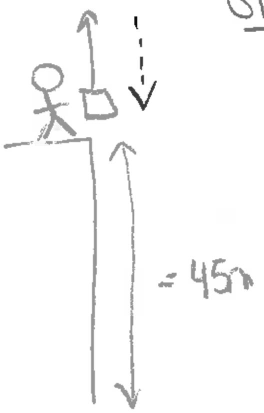
2nd

$d = v_i t + \frac{1}{2} a t^2$
$d = \frac{1}{2} a t^2$
$t^2 = \frac{2d}{a}$
$t = \sqrt{\frac{2d}{a}} = \sqrt{\frac{2(-11.48)}{-9.8}} = 1.531 s$

$t_{total} = t_1 + t_2$
$= 3.06 s$
$= 3.1 s$

Example: A student stands on the edge of a 45.0 m high cliff. They throw their physics homework straight up in the air at 12.0 m/s.

a. How long does it take to come back down to the same height as the student?



Given: $v_i = 12$ m/s
$a = -9.8$ m/s²
$v_{peak} = 0$ m/s
$v_f = -12$ m/s

Need: t

$a = \frac{v_f - v_i}{t}$

$t = \frac{v_f - v_i}{a}$

$= \frac{12 \text{ m/s} - 12 \text{ m/s}}{-9.8 \text{ m/s}}$

$= 2.449 =$ **2.45 s**

* can also calculate t up + then multiply by 2 because t total = t up + t down (t up = t down to same height)

b. If it falls all the way to the bottom of the cliff, how fast is it traveling when it hits the ground?

Given: $v_i = 12$ m/s
$a = -9.8$ m/s²
$d = -45$ m

Need: v_f

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

$v_f = \sqrt{v_i^2 + 2ad}$

$= \pm\sqrt{(12 \text{ m/s})^2 + 2(-9.8 \text{ m/s}^2)(-45 \text{ m})}$

$= \pm 32.0$ m/s

because we took $\sqrt{\ }$

+ve doesn't make any sense so keep only "−"

$v_f = -32.0$ m/s

MOP Connection: None

1. A rock is dropped from a rest position at the top of a cliff and free falls to the valley below. Assuming negligible air resistance, use kinematic equations to determine the distance fallen and the instantaneous speeds after each second. Indicate these values on the odometer (distance fallen) and the speedometer views shown to the right of the cliff. Round all odometer readings to the nearest whole number.

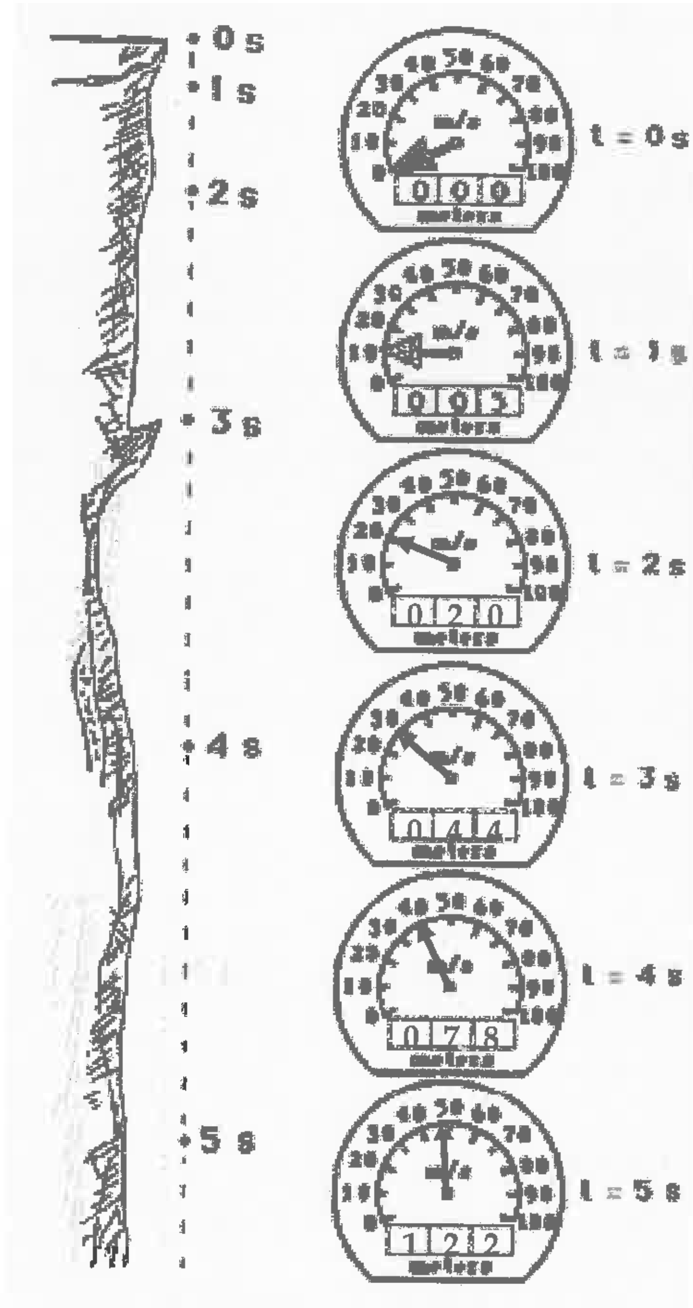
   Show a sample calculation below:

   Use $d =$ ~~$v_o \cdot t$~~ $+ \frac{1}{2} \cdot a \cdot t^2$

   For t = 3.0 seconds

   $d = \frac{1}{2} \cdot (-9.8\ m/s^2) \cdot (3.0\ s)^2$

   d = 44.1 m = ~44 m



2. At which of the listed times is the acceleration the greatest? Explain your answer.

   The acceleration is the same throughout the fall. It is a constant value of $9.8\ m/s^2$ in the downward direction.

3. At which of the listed times is the speed the greatest? Explain your answer.

   The object accelerates for the entire fall. So the speed is greatest at the largest time value - that is, at 5.0 seconds.

4. If the falling time of a free-falling object is doubled, the distance fallen increases by a factor of four. Identify two times and use the distance fallen values to support your answer.

   At t=4.0 s, the d = -78.4 m and at t=2.0 s, the d = -19.6 m. The distance fallen at 4.0 s is four times larger that at 2.0 s.