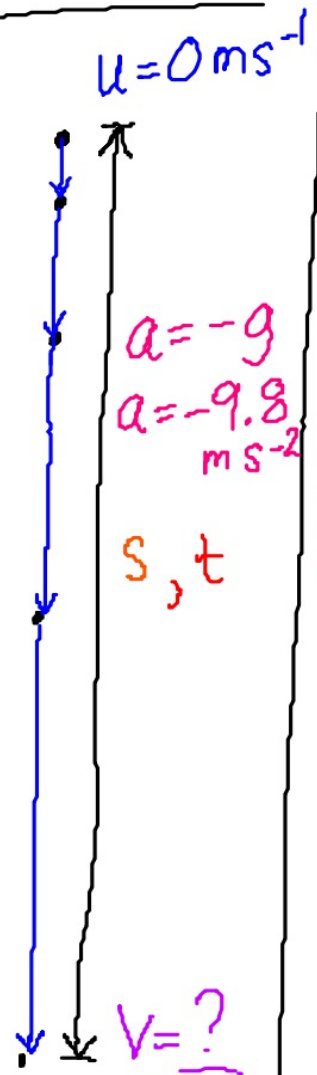
Free Fall Notes:

- vertical motion (up (+) or down (−))
- neglect air resistance
- acceleration of gravity (g)
  - ↳ $g = 9.8\ m\,s^{-2}$, down
  - ↳ $a = -9.8\ m\,s^{-2}$
  - $(a = -g)$
- use kinematic equations
  - ↳ $v = u + at$
  - ↳ $s = ut + \frac{1}{2}at^2$
  - ↳ $v^2 = u^2 + 2as$
  - ↳ $s = \frac{(u+v)}{2}t$

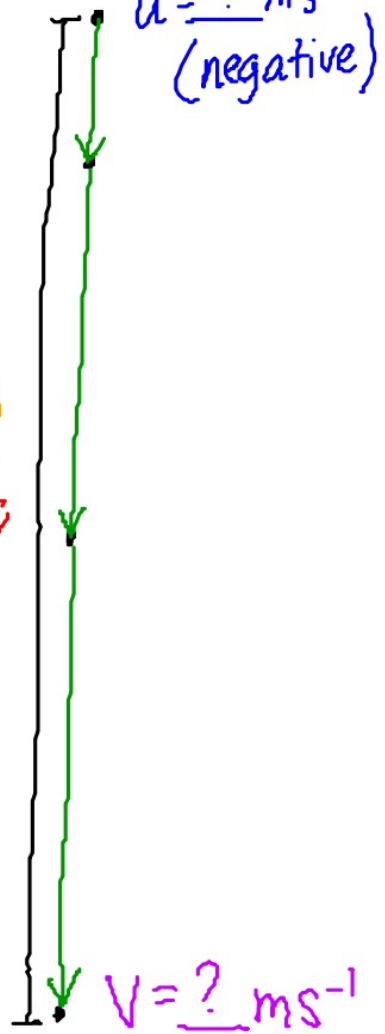
Particle Models

1. Object dropped
2. Object thrown downward
3. Object thrown up and then falls back down.

Object dropped

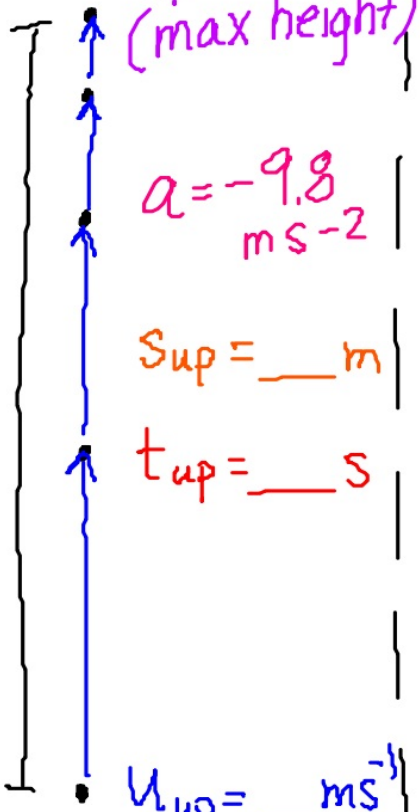


Object thrown down

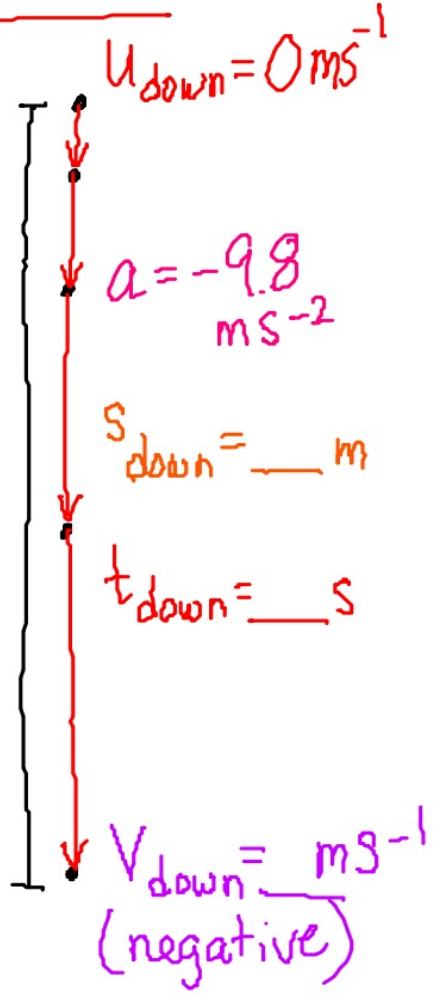


Object thrown up and then falls down

UP



DOWN



Example Problem:

At 1.5 m above the ground, a ball is thrown upward at a speed of 3.5 ms^{-1}.

(a) Determine the maximum height.

(b) How long does it take for the ball to hit the ground?

(c) At what speed does the ball hit the ground?

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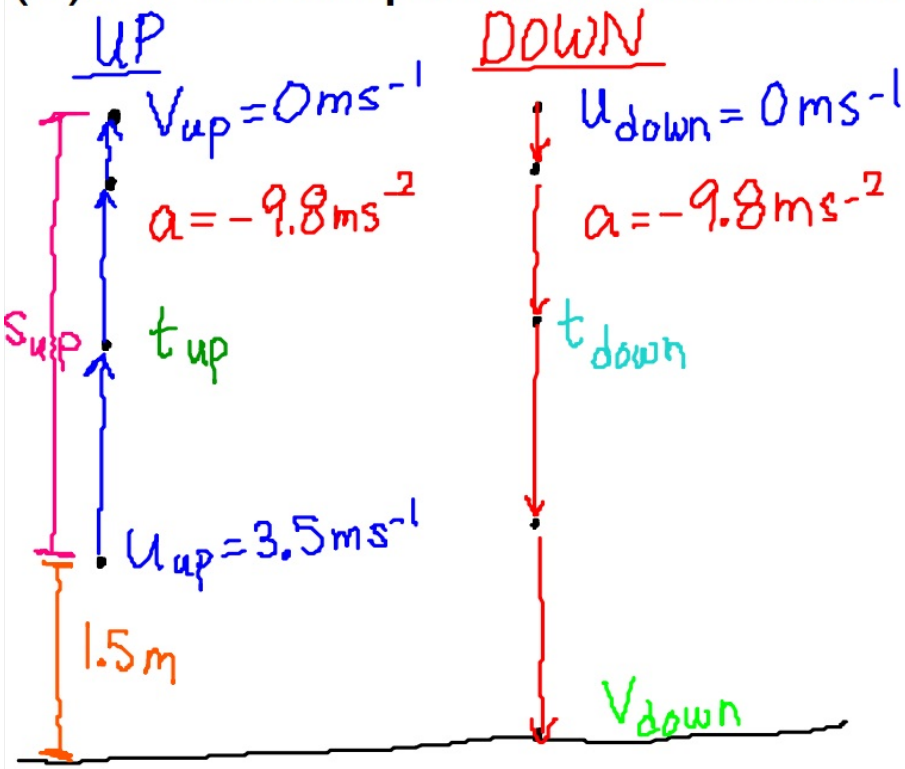
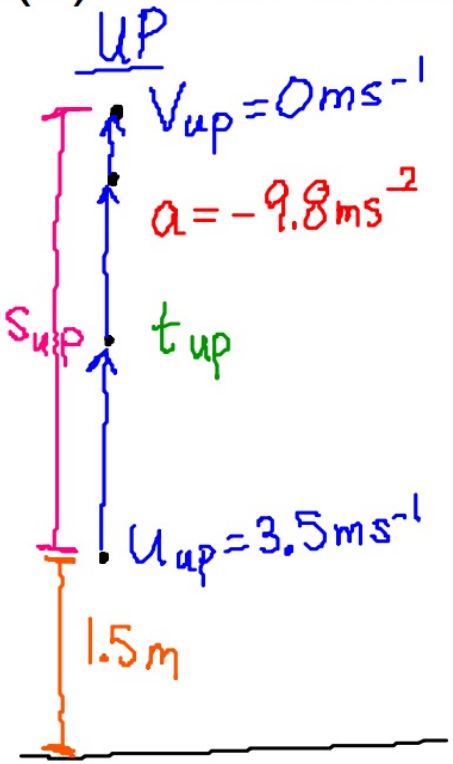


(a) Determine the maximum height.



$u = 3.5\ ms^{-1}$

$v = 0\ ms^{-1}$

$a = -9.8\ ms^{-2}$

$h = s_{up} + 1.5m$

$s_{up} =$ ____ m

$v^2 = u^2 + 2as \rightarrow s = (v^2 - u^2)/2a$

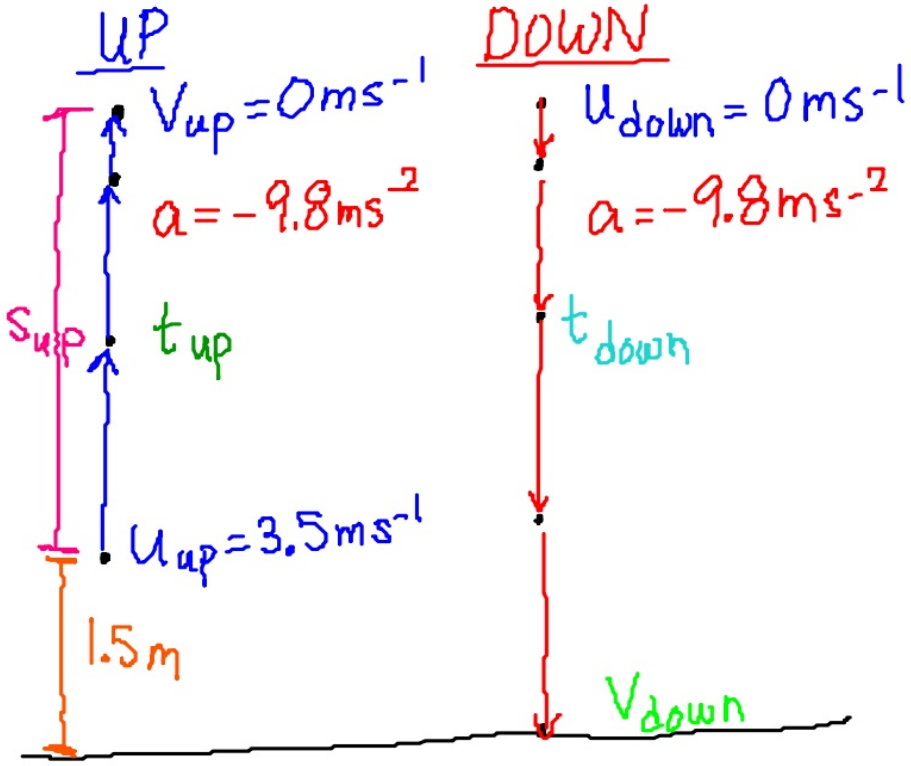
$s = ((0)^2 - (3.5)^2)/2(-9.8)$

$s = 0.625$ m

$h = 0.625 + 1.5 = 2.125$

$h = 2.1$ m

(b) How long does it take for the ball to hit the ground?



$u_{up} = 3.5\ ms^{-1}$
$s_{up} = 0.625\ m$
$a = -9.8\ ms^{-2}$
$v_{up} = 0\ ms^{-1}$
$u_{dn} = 0\ ms^{-1}$
$s_{dn} = -2.1m$

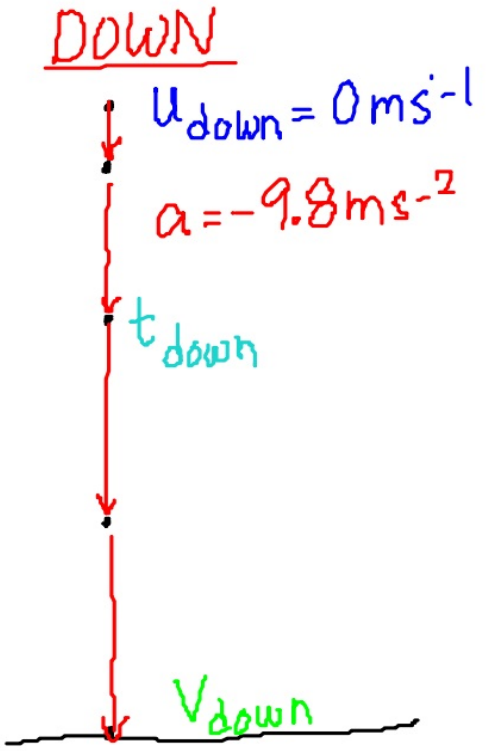
$t_{total} = t_{up} + t_{dn} =$ ____ s

$v = u + at \rightarrow t_{up} = (v_{up} - u_{up})/a$
$t_{up} = (0 - 3.5)/(-9.8) = .3571$ s

$s = ut + (1/2)\ a\ t^2 = (1/2)\ a\ t^2$
$t_{dn} = \text{sqrt}\ (2s_{dn}/a)$
$t_{dn} = \text{sqrt}\ (2(-2.1)/(-9.8)) = .6547$ s

$t_{total} = 1.0s$

(c) At what speed does the ball hit the ground?



$t_{dn} = .6547$ s

$u_{dn} = 0$ ms^{-1}

$a = -9.8$ ms^{-2}

$s_{dn} = -2.1$ m

$v_{dn} =$ _____ ms^{-1}

$v = u + at = (0) + (-9.8)(.6547) = 6.4$ ms^{-1}

HW Problem #1

A stone is dropped from the top of a cliff. It hits the ground below after 3.25 s. How high is the cliff?

$t = 3.25$

$a = -9.8\ ms^{-2}$

$u = 0\ ms^{-1}$

$s = \_\_\_\_\ m$

$s = ut + (1/2)\ a\ t^2$

$s = (0)(3.25) + (1/2)\ (-9.8)\ (3.25)^2$

$s = 51.8\ m$

HW Problem #2

A ballplayer catches a ball 3.0 s after throwing it vertically upward. With what speed did he throw it, and what height did it reach?

t (total) = 3.0 s

$v_{up} = 0\ ms^{-1}$

$a = -9.8\ ms^{-2}$

$u_{down} = 0\ ms^{-1}$

s (total) = 0 m ($|s_{up}| = |s_{down}|$)

(i) u_{up} = _____ ms^{-1}

(ii) height = s_{up} = ___ m

Assumption: B/c $|s_{up}| = |s_{down}|$ then t (total) = 2* t_{up}

So, $t_{up} = 1.5$ s

(i) $v = u + at$ therefore $u = v - at = (0) - (-9.8)(1.5) = 14.7 = 15\ ms^{-1}$

(ii) $s = ut + (1/2)at^2 = (15)(1.5) + (1/2)(-9.8)(1.5)^2 = 11.475 = 11$ m

HW Problem #3

A hot-air balloon is descending at a rate of 2.0 m/s when a passenger drops a camera. If the camera is 45 m above the ground when it is dropped

- How long does it take for the camera to reach the ground?
- What is its velocity just before it lands?

$u = -2.0\ ms^{-1}$
$s = -45\ m$
$a = -9.8\ ms^{-2}$

(i) t = ____ s
(ii) v = ____ ms^{-1}

(ii) $v^2 = u^2 + 2as \rightarrow v = \text{sqrt}\ (u^2 + 2as) = \text{sqrt}\ ((-2.0)^2 + 2(-9.8)(-45)) =$
$v = -3.0 \times 10\ m$
(i) $v = u + at \rightarrow t = (v - u)/a = (-29.77 - (-2.0))/(-9.8) = 2.8$ s or 2.9 s

Free Fall Classwork:

36. (II) A baseball is hit nearly straight up into the air with a speed of 22 m/s. (*a*) How high does it go? (*b*) How long is it in the air?

[redacted]

38. (II) An object starts from rest and falls under the influence of gravity. Draw graphs of (*a*) its speed and (*b*) the distance it has fallen, as a function of time from $t = 0$ to $t = 5.00$ s. Ignore air resistance.

39. (II) A helicopter is ascending vertically with a speed of 5.20 m/s. At a height of 125 m above the Earth, a package is dropped from a window. How much time does it take for the package to reach the ground? [*Hint*: The package's initial speed equals the helicopter's.]