Uniformly Accelerated Motion Sample Problems

Thursday, October 29, 2015 7:28 AM

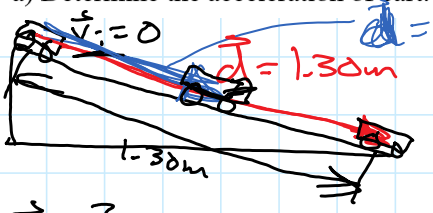
Physics 11 Kinematics Part 2 Sample Problems:
Uniformly Accelerated Motion

All problems involving uniformly accelerated motion must be solved using one or more of the four equations governing uniformly accelerated motion:

$$\boxed{\mathbf{d} = \mathbf{v}_i t + \frac{1}{2}\mathbf{a}t^2} \qquad \mathbf{d} = \left(\frac{\mathbf{v} + \mathbf{v}_i}{2}\right)t \qquad \mathbf{v}^2 = \mathbf{v}_i^2 + 2\mathbf{a}\mathbf{d} \qquad \mathbf{v} = \mathbf{v}_i + \mathbf{a}t$$

1. A dynamics cart is made to roll down an inclined plane starting from rest. The inclined plane is 1.30 m long. The cart reaches the bottom of the incline 1.80 s after it is released.

a) Determine the acceleration of cart.



$\vec{d} = \frac{1}{2}(1.30)$

$t = 1.80\,s$

$\vec{a} = ?$
(no value of $\vec{v}$).

$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$; $\vec{v}_i = 0$,

$\therefore \vec{d} = \frac{1}{2}\vec{a}t^2$

It is preferred that you do the algebra first.

$2\vec{d} = 2\left(\frac{1}{2}\right)\vec{a}t^2$

$\frac{2\vec{d}}{t^2} = \frac{\vec{a}t^2}{t^2}$ $\quad \vec{a} = \frac{2\vec{d}}{t^2} = \frac{2(1.30)m}{1.80^2 s}$

$\vec{a} = 0.802469..$

$\therefore \vec{a} = 0.802\,m/s^2$ (down the incline)

Or $\quad \vec{d} = \cancel{\vec{v}_0 t}^{0} + \frac{1}{2}\vec{a}t^2$

$\rightarrow 1.30 = \frac{1}{2}\vec{a}(1.80^2) \qquad \vec{a} = 0.802...$

$\frac{1.30}{\frac{1}{2}(1.80^2)} = \frac{\frac{1}{2}\vec{a}(1.80^2)}{\frac{1}{2}(1.80^2)}$

$\vec{a} = \frac{1.30}{\frac{1}{2}(1.80^2)} = 0.8024...$ etc.

v = speed
$\vec{v}$ = velocity

b) Determine the speed of the cart at the bottom of the incline.

$v = ?$ (need $\vec{v}$)
$\vec{v}_i = 0$
$\vec{d} = 1.30\,m$
$\vec{a} = 0.802469..\,m/s^2$
all $\vec{s}$

$\boxed{\vec{v} = \vec{v}_i + \vec{a}t}$ $\qquad \vec{v}^2 = \vec{v}_i^2 + 2\vec{a}\vec{d}$

or $\quad \vec{d} = \left(\frac{\vec{v} + \vec{v}_i}{2}\right)t$

$\vec{v} = 0 + (0.802469..)(1.80)$

all 5 $\left\{ \begin{array}{l} d = 1.30\,m \\ \vec{a} = 0.802469..\,m/s^2 \\ t = 1.80\,s \end{array} \right.$

$\vec{v} = 0 + (0.802469..)(1.80)$

$\vec{v} = 1.4444...$

Do not $\longrightarrow$ ∴ speed, $v = \underline{1.44\,m/s}$

c) Determine the time it takes for the cart to travel half-way down the incline.

$t = ?$

$\vec{a} = 0.802469..\,m/s^2$

$\vec{v}_i = 0$

$\vec{d} = \frac{1}{2}(1.30)$

$= 0.650\,m$

no $\vec{v}$

Note: $\vec{v} \neq \underbrace{1.444..}_{\text{at bottom}}\,m/s$!!

$\vec{d} = \cancel{\vec{v}_i t}^{\,0} + \frac{1}{2}\vec{a}t^2$

$\vec{d} = \frac{1}{2}\vec{a}t^2$ solve for t

$\frac{2\vec{d}}{\vec{a}} = \frac{\vec{a}t^2}{\vec{a}}$ $\quad \sqrt{t^2} = \sqrt{\frac{2\vec{d}}{\vec{a}}}$

$t = \sqrt{\frac{2\vec{d}}{\vec{a}}} = \sqrt{\frac{2(0.650)}{0.802469..}}$

$t = 1.27279.. = \underline{1.27\,s}$.

$\sqrt{t^2} = \sqrt{\frac{2\vec{d}}{\vec{a}}}$ square root BOTH sides

t

d) Determine the speed of the cart when it is half-way down the incline.

$v = ?$ (need $\vec{v}$)

$\vec{v}_i = 0$

$\vec{a} = 0.802469..\,m/s^2$

$\vec{d} = 0.650\,m$

$t = 1.27279..\,s$

$\vec{v} = \vec{v}_i + \vec{a}t$ $\quad \vec{v}^2 = \vec{v}_i + 2\vec{a}\vec{d}$

unrounded values

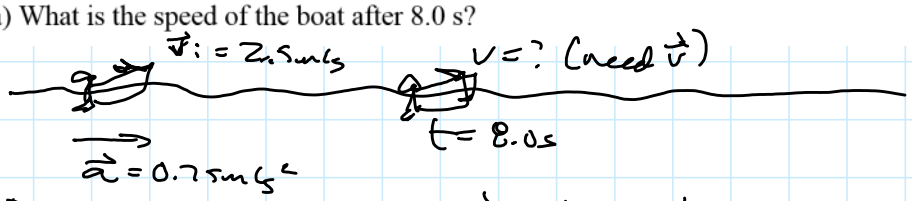
$\vec{v} = 0 + (0.802469..)(1.27279..)$

$\vec{v} = 1.021326..$

∴ speed, $v = \underline{1.02\,m/s}$.

2. A speedboat accelerates from an initial speed of 2.5 m/s at a constant rate of 0.75 m/s^2 forward.

a) What is the speed of the boat after 8.0 s?



$\vec{v}_i = 2.5\,m/s$

$\vec{a} = 0.75\,m/s^2$

$t = 8.0\,s$

$\vec{v} = \vec{v}_i + \vec{a}t$

⋮ etc.

$v = ?$ (need $\vec{v}$)

$\vec{v} = 8.5\ m/s$

$\therefore$ Speed $v = 8.5\ m/s$

b) How far does the boat travel during the first 5.0 s after it began to accelerate?

$d = ?$

$t = 5.0\ s$

$\vec{v}_i = 2.5\ m/s$

$\vec{a} = 0.75\ m/s^2$

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

$\vec{d} = (2.5)(5.0) + \frac{1}{2}(0.75)(5.0)^2$

$\vec{d} = 21.875\ldots \quad \therefore d = 22\ m.$

or you could find $\vec{v}$ first.

$\vec{v} = \vec{v}_i + \vec{a}t = 2.5 + (0.75)(5.0)$

$= 6.25\ m/s$ (2sf)

then $\vec{d} = \left(\frac{\vec{v} + \vec{v}_i}{2}\right)t = \left(\frac{6.25 + 2.5}{2}\right)(5.0)$

$\vec{d} = 21.875\ldots$

$\therefore d = 22\ m.$

c) How long does it take for the boat to reach a speed of 15.0 m/s?

($t = 17\ s$)

$t = ?$

$\vec{v}_i = 2.5\ m/s$

$\vec{v} = 15.0\ m/s$

$\vec{a} = 0.75\ m/s^2$

$\vec{v} = \vec{v}_i + \vec{a}t$ solve for t.

$\frac{\vec{v} - \vec{v}_i}{\vec{a}} = \frac{\cancel{\vec{a}} t}{\cancel{\vec{a}}}$

$t = \frac{\vec{v} - \vec{v}_i}{\vec{a}} = \frac{15.0 - 2.5}{0.75} = 16.666\ldots$

$\therefore t = 17\ s.$

d) How long does it take for the boat to travel 1.0×10^2 m?

($t = 13\ s$).

$t = ?$

$\vec{d} = 1.0 \times 10^2\ m$

$\vec{v}_i = 2.5\ m/s$

$\vec{a} = 0.75\ m/s^2$

$\vec{v} = ?$

no $\vec{v}$

$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$ solve for t

$1.0 \times 10^2 = 2.5t + \frac{1}{2}(0.75)t^2$??

This can be solved in two steps.

Find $\vec{v}$ first, then t.

$\vec{v}^2 = \vec{v}_i^2 + 2\vec{a}\vec{d}$

$\vec{v} = \pm\sqrt{(2.5)^2 + 2(0.75)(1.0 \times 10^2)}$

$\vec{v}^2 = \vec{v}_i^2 + 2\vec{a}\vec{d}$

$\vec{v} = \pm\sqrt{(2.5)^2 + 2(0.25)(1.0\times10^2)}$

$\vec{v} = +12.5$ m/s or $\cancel{-12.5}$ extraneous

Then

$\vec{v} = \vec{v}_i + \vec{a}t$ solve for t

$\frac{\vec{v} - \vec{v}_i}{\vec{a}} = \frac{\cancel{\vec{a}}t}{\cancel{\vec{a}}}$ $\quad t = \frac{\vec{v} - \vec{v}_i}{\vec{a}} = \frac{(12.5 - 2.5)}{0.25}$

$t = 13.333 = \underline{13\,s}$

$0.375t^2 + 2.5t - 1.0\times10^2 = 0$

$t = \frac{-2.5 \pm \sqrt{(2.5)^2 - 4(0.375)(-1.0\times10^2)}}{2(0.375)}$

$t = \cancel{-20}$ extraneous, $13.333\ldots$ $\therefore$ $\underline{t = 13\,s}$.

3. A car that was initially traveling with a velocity of 80.0 km/h East slows uniformly to a velocity of 30.0 km/h East upon entering a school zone. It takes the car 5.00 s to slow to its final speed.

a) What was the magnitude (size) of the car's acceleration (in units of m/s²) during the 5.00 s interval?

$\vec{v}_i = 80.0$ km/h E
$= 22.2$ m/s Don't round

$\vec{v} = 30.0$ km/h E
$= 8.33$ m/s Don't round

$t = 5.00$ s

$\vec{a} = ?$ (need $\vec{a}$)

* Before anything else, deal with units.

You do NOT need to show how you converted km/h to m/s. ÷ 3.6
- Don't round the converted values!!

$\vec{v} = \vec{v}_i + \vec{a}t$ solve for $\vec{a}$

$\vec{v} = \cancel{\vec{v}_i} + \vec{a}t$
$-\vec{v}_i \quad -\vec{v}_i$
$\frac{\vec{v} - \vec{v}_i}{t} = \frac{\vec{a}\cancel{t}}{\cancel{t}}$

$\vec{a} = \frac{\vec{v} - \vec{v}_i}{t} = \frac{+8.33 - +22.2}{5.00}$

$\vec{a} = \frac{-13.8}{5.00} = -2.7777\ldots$

- The "rate of acceleration" is the measure of the size of the acceleration only.

So, rate of acceleration, $a = 2.78$ m/s²
SCALAR

b) What was the direction of the car's acceleration?

West. [We know this because $\vec{a}$ is negative].

c) How far did the car travel during the 5.00 s interval?

$d = ?$ need $\vec{d}$.

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

$t = 5.00\,s$
$\vec{v}_i = 22.\overline{2}\ m/s$
$\vec{v} = 8.\overline{33}\ m/s$
$\vec{a} = -2.\overline{77}\ m/s^2$

$$\boxed{\vec{d} = \left(\frac{\vec{v} + \vec{v}_i}{2}\right)t}$$

$$\vec{d} = \left(\frac{8.\overline{33} + 22.\overline{2}}{2}\right)(5.00)$$

$\vec{d} = 76.3888...\ m$ (3sf)

add this to your solution.

$\longrightarrow$ ∴ distance, $d = 76.4\,m$

d) How far did the car travel during the first 3.00 s of the 5.00 s interval?

$t = 3.00\,s$
$\vec{v}_i = 22.\overline{2}\ m/s$
$\vec{a} = -2.\overline{77}\ m/s^2$

$d = ?$ need $\vec{d}$

No $\vec{v}$!

• Note: you cannot use $\vec{v} = 8.\overline{33}\ m/s$ for this part. This is because $t = 3.00\,s$ not $5.00\,s$!

$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$
$= (22.\overline{2})(3.00) + \frac{1}{2}(-2.\overline{77})(3.00)^2$

$\vec{d} = 54.1666...\ m$

∴ distance, $d = 54.2\,m$.

e) How fast was the car traveling after the first 3.00 s of the 5.00 s interval?

speed

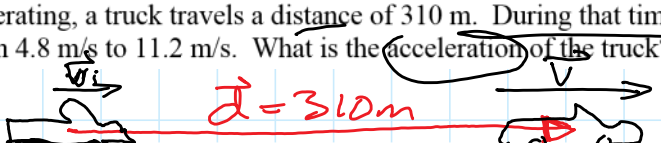
$\vec{v}_i = 22.\overline{2}\ m/s$
$\vec{a} = -2.\overline{77}\ m/s^2$
$t = 3.00\,s$
$\vec{d} = 54.1664\ m$

$v = ?$ need $\vec{v}$

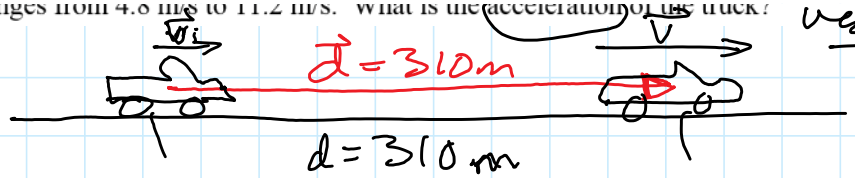
$\vec{v} = \vec{v}_i + \vec{a}t$
$= 22.\overline{2} + (-2.\overline{77})(3.00)$
$\vec{v} = 13.888...\ m/s$

∴ speed, $v = 13.9\,m/s$.

4. While accelerating, a truck travels a distance of 310 m. During that time, the truck's speed changes from 4.8 m/s to 11.2 m/s. What is the acceleration of the truck? vector.



changes from 4.8 m/s to 11.2 m/s. What is the acceleration of the truck? vector.



$\vec{d} = 310\,m$
$\vec{v}_i = +8\,m/s$
$\vec{v} = 11.2\,m/s$
} all forward.
$\vec{a} = ?$
no t

$\vec{v}^2 = \vec{v}_i^2 + 2\vec{a}\vec{d}$ solve for $\vec{a}$

$$\left(\frac{\vec{v}^2 - \vec{v}_i^2}{2\vec{d}} = \frac{\cancel{2}\vec{a}\cancel{\vec{d}}}{\cancel{2\vec{d}}}\right)$$

$$\vec{a} = \frac{\vec{v}^2 - \vec{v}_i^2}{2\vec{d}} = \frac{11.2^2 - 4.8^2}{2(310)}$$

$$= 0.165161290\ldots$$

$\therefore \vec{a} = 0.165\,m/s^2$ (forward)

OR

$$\vec{d} = \left(\frac{\vec{v} + \vec{v}_i}{2}\right)t$$

this can be solved for t $\left(t = \frac{2\vec{d}}{\vec{v} + \vec{v}_i}\right)$

then use t in $\vec{v} = \vec{v}_i + \vec{a}t$ to get $\vec{a}$

$$\left(\vec{a} = \frac{\vec{v} - \vec{v}_i}{t}\right)$$

5. A bus begins to slow down at a constant rate. After 5.6 s, it has reached a speed of 6.5 m/s and has traveled 63 m. What was the speed of the bus when it started to accelerate?

$t = 5.6\,s$
$\vec{v} = 6.5\,m/s$ (forward)
$\vec{d} = 63\,m$ (forward)

$v_i = ?$ (need $\vec{v}_i$)

no $\vec{a}$.

$$\vec{d} = \left(\frac{\vec{v} + \vec{v}_i}{2}\right)t$$

solve for $\vec{v}_i$!

$$2\vec{d} = \cancel{2}\left[\frac{\vec{v} + \vec{v}_i}{\cancel{2}}\right]t$$

$$\frac{2\vec{d}}{t} = \frac{(\vec{v} + \vec{v}_i)\cancel{t}}{\cancel{t}}$$

$$\frac{2\vec{d}}{t} = \vec{v} + \vec{v}_i$$

$$\vec{v}_i = \frac{2\vec{d}}{t} - \vec{v} = \frac{2(63)}{5.6} - 6.5$$

$$\vec{v}_i = 22.5 - 6.5 = 16\,m/s$$

2 sf

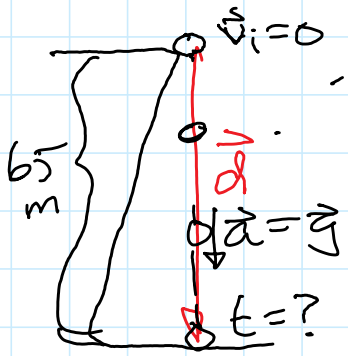
Precise to mos.

$\therefore$ initial speed, $v_i = 16\,m/s$.

Projectiles in One-Dimension Sample Problems

1. A rock falls from rest from the top of a 65 m high cliff. Air friction is negligible as it falls.

a) How long does it take for the rock to reach the ground at the bottom of the cliff?



- Because I call downward vectors negative.

$\vec{v}_i = 0$
$\vec{a} = \vec{g} = -9.80\,m/s^2$
$\vec{d} = -65\,m$
$t = ?$

$$\vec{d} = \cancel{\vec{v}_i t}^{\,0} + \tfrac{1}{2}\vec{g}t^2$$

$$\vec{d} = \tfrac{1}{2}\vec{g}t^2 \quad \text{solve for } t$$

$$\left(2\vec{d} = \cancel{\tfrac{1}{2}}\vec{g}t^2 \quad \frac{2\vec{d}}{\vec{g}} = \frac{\cancel{\vec{g}}t^2}{\cancel{\vec{g}}} \quad \sqrt{t^2} = \sqrt{\frac{2\vec{d}}{\vec{g}}}\right)$$

$$t = \sqrt{\frac{2\vec{d}}{\vec{g}}}$$

$$t = \sqrt{\frac{2(-65)}{-9.80}} = 3.642152..$$

$$\therefore t = 3.6\,s$$

b) How fast is the rock moving after falling for 1.50 s?

$t = 1.50\,s$
$v = ?$ need $\vec{v}$
$\vec{a} = \vec{g} = -9.80\,m/s^2$
$\vec{v}_i = 0$
no $\vec{d}$

$$\vec{v} = \cancel{\vec{v}_i}^{\,0} + \vec{g}t$$
$$\vec{v} = \vec{g}t = (-9.80)(1.50)$$
$$\vec{v} = -14.7\,m/s$$

velocity is downward $\therefore$ −

$\therefore$ speed, $v = 14.7\,m/s$

c) How far has the rock fallen after 2.00 s?

$d = ?$ need $\vec{d}$
$t = 2.00\,s$
$\vec{v}_i = 0$

$$\vec{d} = \cancel{\vec{v}_i t}^{\,0} + \tfrac{1}{2}\vec{g}t^2$$
$$\vec{d} = \tfrac{1}{2}\vec{g}t^2 = \tfrac{1}{2}(-9.80)(2.00)^2$$

$t = 2.00\,s$
$\vec{v}_i = 0$
$\vec{a} = \vec{g} = -9.80\,m/s^2$

$\vec{d} = \frac{1}{2}\vec{g}t^2 = \frac{1}{2}(-9.80)(2.00)^2$
$\vec{d} = -19.6\,m$

*The $\vec{v}$ from b) can't be used!

$\therefore$ distance, $d = 19.6\,m$

d) How fast is the rock traveling just as it lands on the ground at the bottom of the cliff?

$v = ?$ need $\vec{v}$
$\vec{v}_i = 0$
$\vec{a} = \vec{g} = -9.80\,m/s^2$
$\vec{d} = -65\,m$

$t = 3.642156..\,s$ (from (a))

$\vec{v} = \cancel{\vec{v}_i}^{\,0} + \vec{g}t$

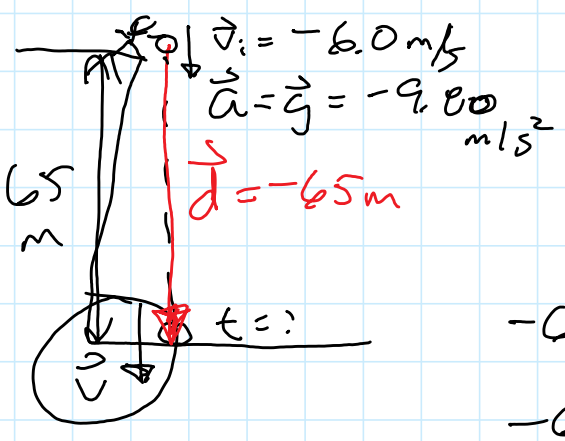
$\vec{v} = (-9.80)(3.642..)$ 2sf
$\vec{v} = -35.693..$
$\therefore$ speed $= 36\,m/s$

$\vec{v}^2 = \cancel{\vec{v}_i^2}^{\,0} + 2\vec{g}\vec{d}$
$\vec{v}^2 = 2\vec{g}\vec{d}$
$\sqrt{\vec{v}^2} = \pm\sqrt{2\vec{g}\vec{d}}$ *
$\vec{v} = \sqrt{2(-9.80)(-65)}$
$= \cancel{35.6931..}\,m/s$ extraneous
or $-35.6931..\,m/s$

$\vec{v}$ is downward $\therefore -$!! when it lands

$\therefore$ Speed, $v = 36\,m/s$.

2. If the rock in Sample Problem 1 were thrown vertically downward with an initial speed of 6.0 m/s, how long would it take the rock to reach the ground at the bottom of the cliff?



- Using only $\vec{v}_i, \vec{a}, \vec{d}$ & t, missing $\vec{v}$

$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{g}t^2$

solve for t ?

$-65 = -6.0t + \frac{1}{2}(-9.80)t^2$

$-65 = -6.0t + -4.90t^2$

To solve with quadratic formula:

$\underbrace{4.90}_{a}t^2 + \underbrace{6.0}_{b}t \underbrace{-65}_{c} = 0$

$$t = \frac{-6.0 \pm \sqrt{(6.0)^2 - 4(4.90)(-65)}}{2(4.90)}$$

extraneous

$2(4.90)$

$= 3.081012\ldots, \cancel{-4.3055\ldots}$ extraneous

$\therefore t = \underline{\underline{3.1\,s}}$

OR

$\vec{v} = ?$
$\vec{v}_i = -6.0\,m/s$
$\vec{a} = \vec{g} = -9.80\,m/s^2$
$\vec{d} = -65\,m$

$\vec{v}^2 = \vec{v}_i^2 + 2\vec{g}\vec{d}$

solve for $\vec{v}$, then use

$\vec{v} = \vec{v}_i + \vec{g}t$ to get t

$\vec{v} = \pm\sqrt{\vec{v}_i^2 + 2\vec{g}\vec{d}}$

$= \pm\sqrt{(-6.0)^2 + 2(-9.80)(-65)}$ ✓✓

You must consider $\pm\sqrt{\ }$ $\longrightarrow$ $= +36.19392214\,m/s,\ \cancel{-36.19392214}$ extraneous

$\vec{v} = \vec{v}_i + \vec{g}t$

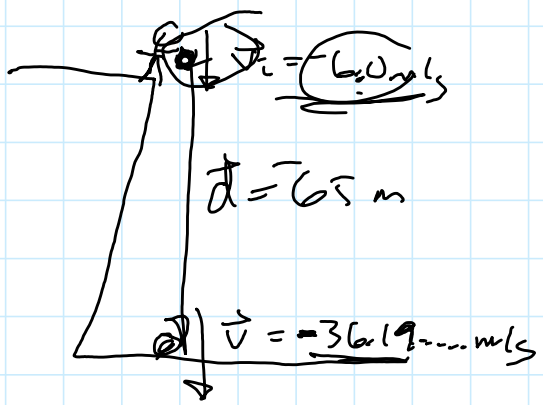
$t = \dfrac{\vec{v} - \vec{v}_i}{\vec{g}}$

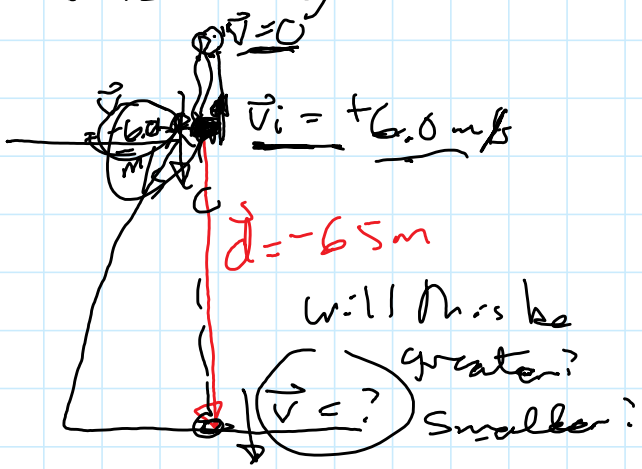
$= \dfrac{36.1939\ldots - -6.0}{-9.80}$

$\vec{v} = \vec{v}_i + \vec{g}t$
$-\vec{v}_i \quad -\vec{v}_i$
$\dfrac{\vec{v} - \vec{v}_i}{\vec{g}} = \dfrac{\vec{g}t}{\vec{g}}$

$t = 3.081012\ldots = \underline{\underline{3.1\,s}}$

Q: If the rock were initially thrown upward with a speed of 6.0 m/s, what would its velocity be when it hits the ground?





$\vec{v}^2 = \vec{v}_i^2 + 2\vec{g}\vec{d}$

$$\vec{v}^2 = \vec{v}_i^2 + 2\vec{g}\vec{d}$$

$$\vec{v} = \pm\sqrt{(-6.0)^2 + 2(-9.80)(-65)}$$

$$= -36.19\ldots \text{ m/s}$$

(same as before!!)

$(-6.0)^2 = 36$

$(+6.0)^2 = 36$

In the case where it is thrown upward, when the rock returns to its launch point, its velocity will be -6.0 m/s.

3. A marble is fired straight upward by a slingshot. The marble is traveling with a speed of 24.5 m/s when it leaves the slingshot. Ignore any effects of air friction.

a) What is the speed of the marble 3.0 s after it leaves the slingshot? Is it rising or falling at this time?

speed $v = ?$ (need $\vec{v}$) velocity

$\vec{a} = \vec{g} = -9.80$ m/s^2

$\vec{v} = \vec{v}_i + \vec{g}t$

$t = 3.0$ s

$\vec{v}_i = +24.5$ m/s

$$\vec{v} = +24.5 + (-9.80)(3.0)$$

$$= +24.5 + -29.4$$

$$\vec{v} = -4.9 \text{ m/s}$$

precise to one place only!

$\therefore$ speed, $v = \cancel{4.9}$ m/s. It is falling. $\vec{v}$ is downward.

speed, $v = 5$ m/s NOTE: this value is only precise to the one place.

b) How high above the point where it leaves the slingshot is the marble after 3.50 s?

h = height is a scalar quantity equal to some measure of vertical distance.

In this case, h = size of $\vec{d}$.

$\vec{v}_i = +24.5$ m/s

$t = 3.50$ s

$\vec{a} = \vec{g} = -9.80$ m/s^2

$\vec{d} = ?$

(no $\vec{v}$)

$\vec{v} = \vec{v}_i + \vec{g}t$

$\vec{d} = (\vec{v} + \vec{v}_i)t$

$\vec{v}^2 = \vec{v}_i^2 + 2\vec{g}\vec{d}$

$$\vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{g}t^2$$

$= (+24.5)(3.50) + \frac{1}{2}(-9.80)(3.50)^2$

$\vec{d} = +85.75 + -60.025$

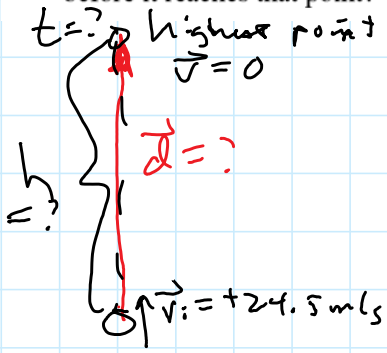
$= +25.725\,m$

$\therefore h = 25.7\,m$

c) What is the marble's instantaneous velocity at its highest point of flight? What is its acceleration at this point?

At the highest point of flight (apogee), $\vec{v} = 0$ and $\vec{a} = \vec{g}$.

d) What maximum height above its launch-point does the marble attain? How much time passes before it reaches that point?



$\vec{v}^2 = \vec{v}_i^2 + 2\vec{g}\vec{d}$

$\vec{d} = \frac{\vec{v}^2 - \vec{v}_i^2}{2\vec{g}}$

$\vec{d} = \frac{0^2 - (+24.5)^2}{2(-9.80)}$

$\vec{d} = \frac{0 - 600.25}{-19.6} = 30.625\,m$

$\vec{v}^2 = \vec{v}_i^2 + 2\vec{g}\vec{d}$

$-\vec{v}_i^2 \quad -\vec{v}_i^2$

$\frac{\vec{v}^2 - \vec{v}_i^2}{2\vec{g}} = \frac{2\vec{g}\vec{d}}{2\vec{g}}$

$\therefore$ max. height, $h = 30.6\,m$

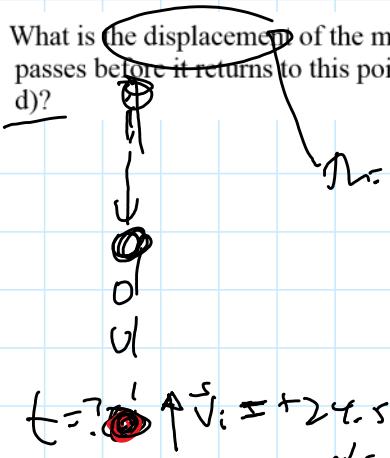
$\vec{v}_i = +24.5\,m/s$
$\vec{v} = 0$
$t = ?$
$\vec{a} = \vec{g} = -9.80\,m/s^2$
$(\vec{d} = +30.625)$

$\vec{v} = \vec{v}_i + \vec{g}t$

$t = \frac{\vec{v} - \vec{v}_i}{\vec{g}} = \frac{0 - +24.5}{-9.80}$

$\boxed{t = 2.50\,s}$

e) What is the displacement of the marble just as it returns to its launch-point? How much time passes before it returns to this point? How does this time compare to the time calculated in part d)?



This is the vector that runs from the launch-point to the position of the marble at each instant in time.

When it gets back to its launch point $\vec{d} = 0$.

total

$\vec{d} \neq$ distance travelled up and down.

$t = ?$

$\boxed{\vec{d} = 0}$

$\vec{v}_i = +24.5\ m/s$

$\vec{a} = \vec{g} = -9.80\ m/s$

There are actually two values of t for which $\vec{d} = 0$.

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{g}t^2$$

Because $\vec{d} = 0$, this simplifies to

$$0 = \vec{v}_i t + \frac{1}{2}\vec{g}t^2$$

Therefore

$$0 = +24.5t + \frac{1}{2}(-9.80)t^2$$

or

$$0 = +24.5t + -4.90t^2$$

$$+4.90t^2 = -24.5t + 4.90t^2$$

$$-24.5t$$

$$4.90t^2 - 24.5t = 0$$

$$t(4.90t - 24.5) = 0$$

$t = 0$ at launch (we don't want this value)

$$4.90t - 24.5 = 0$$

$$4.90t = 24.5$$

$$t = \frac{24.5}{4.90} = \boxed{5.00\ s}$$

This is double the time calculated in part (d).

f) What is the velocity of the marble just as it returns to its launch-point?

$t = 5.00\ s$ } use this!

$\vec{v}_i = +24.5\ m/s$

$\vec{v} = ?$

$\vec{a} = \vec{g} = -9.80\ m/s^2$

$$\vec{v} = \vec{v}_i + \vec{g}t$$

$$= +24.5 + (-9.80)(5.00)$$

$$\vec{v} = -24.5\ m/s$$

NOTICE: that is equal but opposite the launch velocity!

g) Sketch a velocity-time graph (calling upward positive) showing how the velocity changes between the time the marble leaves the slingshot and the time it returns to its launch point.

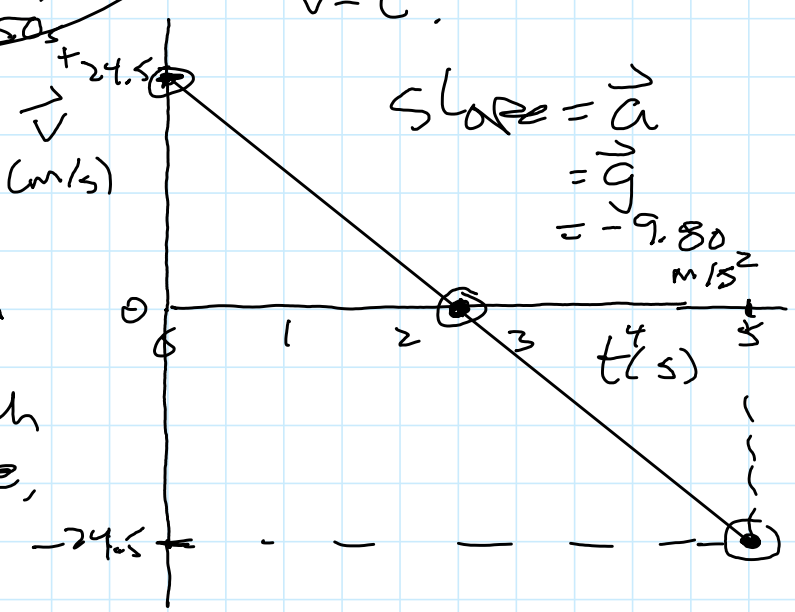
0 highest point, $\vec{v}=0$
$t=2.50\,s$

$\vec{v}-t$.

$\vec{a}=\vec{g}$

$t=5.00\,s$ $\vec{v}=-24.5\,m/s$

$t=0$ $\vec{v}_i=+24.5\,m$



slope $=\vec{a}$
$=\vec{g}$
$=-9.80\,m/s^2$

– When the $\vec{v}-t$ graph is a straight-line, $\vec{a}$ is constants.