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# PHYSICS FOR THE LIFE SCIENCES

## Solution Manual

Created by WebStraw

# Physics for the Life Sciences – Kinematics Solutions

## Introduction:

Dear student,

Thank you for opening this solution manual for the Kinematics chapter of the Physics for the Life Sciences Question Manual. This resource has been created by members of the Education Team at WebStraw who have previously taken an introductory university physics course.

## Purpose:

This resource is meant to supplement the Physics for the Life Sciences Question Manual, by providing solutions to select questions. To access the full question manual, please click here.

## Instructions

We recommend first trying to complete the problems in the question manual on your own. If you get stuck, you can use this resource to view the solution provided by one of our Education Team members. Once you are confident you understand how to solve that question, we recommend solving additional related problems in order to successfully master the topic.

## Disclaimer

This resource assumes that you have a basic understanding of key concepts related to the Kinematics unit in physics. If you are looking to improve your understanding of specific physics content, check out the additional resources provided at the end of the question manual.

Note: There may be more than one correct method to solve some of the problems outlined in the question manual. Thus, the solutions provided may not represent the only acceptable solution.

If you have any comments or feedback regarding this resource or the solutions contained in it, please do not hesitate to contact us at team@webstraw.ca

We wish you the best of luck on your learning journey!

- The WebStraw Education Team

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**A1:**

Given: time = 24 hours
distance = 51.6 km

Required: velocity

Formula: velocity = $\frac{\text{distance}}{\text{time}}$

$1\ km = 1000\ m$

$1\ hr = 60\ minutes = 3600s$

Solve: velocity $= \frac{51.6\ km}{24\ hr} = \boxed{2.15\ km/hr}$

In $\frac{m}{s}$: $2.15 \frac{\cancel{km}}{\cancel{hr}} \left(\frac{1000m}{\cancel{km}}\right)\left(\frac{1\ \cancel{hr}}{3600s}\right) = \boxed{0.597\ \frac{m}{s}}$

direction unknown so this is technically a speed, not a velocity

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**A3:**

Given: density $= 2.7\ \frac{g}{cm^3}$

Required: density (in $kg/m^3$)

Formula: $1\ kg = 1000g$

$1\ m^3 = (100\ cm)^3 = 10^6$

Solve: $2.7 \frac{\cancel{g}}{\cancel{cm^3}} \left(\frac{1\ kg}{1000\ \cancel{g}}\right)\left(\frac{10^6\ \cancel{cm^3}}{1\ m^3}\right) = \boxed{2700\ \frac{kg}{m^3}}$

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**A5:**

Given: Object travels 2x to left, Nx to right diagonally with angle theta to horizontal

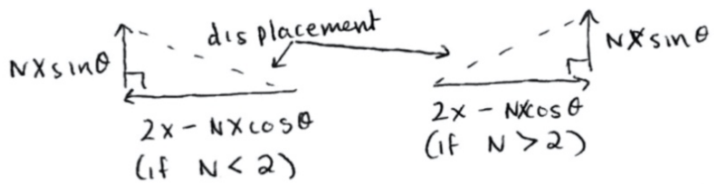

Required: General expression for displacement + displacement in terms of X if $\theta = 45°$ & $N = 1$

Solve: x-component of $2x = 2x$  y-component of $2x = 0$

x-component of $NX = NX\cos\theta$  y-component of $NX = NX\sin\theta$

Total x-components $= 2X - NX\cos\theta$ (since they are in different directions)

Total y-component $= NX\sin\theta$




right angle △ so can use pythagorean's

General expression for displacement $= \boxed{\sqrt{(2X - NX\cos\theta)^2 + (NX\sin\theta)^2}}$

If $\theta = 45$ & $N = 1$: displacement $= \sqrt{(2X - 1X\cos 45)^2 + (1X\cos 45)^2}$

$= \sqrt{\left(2X - \frac{1}{\sqrt{2}}X\right)^2 + \left(\frac{1}{\sqrt{2}}X\right)^2}$

$= \sqrt{(1.3X)^2 + \frac{1}{2}X^2}$

$= \sqrt{1.67X^2 + \frac{1}{2}X^2}$

$= \sqrt{2.17X^2} = \boxed{1.47X}$

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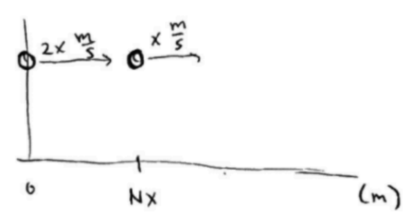
**A7a:**

Given: Parrot 1: $v = X\ \frac{m}{s}$, initial position $= +Nx$ m

Parrot 2: $v = 2x\ \frac{m}{s}$, initial position $= 0$ m

we will assume they are travelling to the right but this doesn't affect calculations




Required: time for Parrot 2 to catch up

Solve: distance $= NX$ m

difference in velocity $= x\ \frac{m}{s} \longrightarrow 2x\ \frac{m}{s} - x\ \frac{m}{s} = x\ \frac{m}{s}$

time $= \frac{\text{distance}}{\Delta\text{velocity}} = \frac{N\cancel{X}\ m}{\cancel{X}\ m/s} = \boxed{N \text{ seconds}}$

**A7b:** *use same reasoning as A7a*

$$\text{time} = \frac{\text{distance}}{\Delta\ \text{velocity}} = \frac{2(NX)\ m}{2(2X\ \frac{m}{s}) - X\ \frac{m}{s}} = \frac{2NX\ m}{3X\ \frac{m}{s}} = \boxed{\frac{2}{3}N \text{ seconds}}$$

time to catch up decreases

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**A11:**

Given: drift rate = 200mm/year

final distance = 50 km

Required: time for drift to occur

Solve: $\text{time} = \frac{\text{distance}}{\text{velocity}} \Rightarrow 200\ \text{mm/year} = 200\frac{\cancel{mm}}{\text{year}}\left(\frac{1\ \text{km}}{10^6\ \cancel{mm}}\right) = 0.0002\ \frac{\text{km}}{\text{year}}$

$$= \frac{50\ \cancel{km}}{0.0002\ \frac{\cancel{km}}{\text{year}}} = \boxed{250\ 000 \text{ years}}$$

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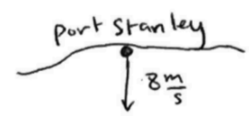
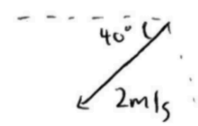
**A13:**




Given: ship velocity (independent of ocean) = 8 m/s

↳ Port Stanley is on North shore of Lake Erie; we will assume this velocity is directed South

Ocean current velocity = 2 m/s 40° S of W




Required: Resultant velocity of ship w/ ocean current

Solve: x-component of ship velocity = 0

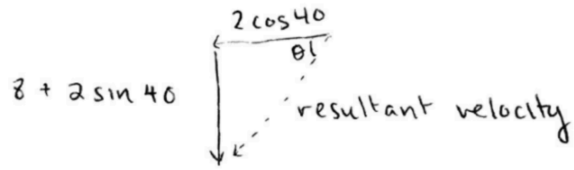
x-component of ocean velocity = $2\cos 40\ \frac{m}{s}$

y-component of ship velocity = $8\ \frac{m}{s}$

y-component of ocean velocity = $2\sin 40\ \frac{m}{s}$

Total x-component = $2\cos 40\ \frac{m}{s}$ (west)

Total y-component = $8\ \frac{m}{s}$ (south) + $2\sin 40\ \frac{m}{s}$ (south)




Resultant velocity $= \sqrt{(2\cos 40)^2 + (8 + 2\sin 40)^2}$

$= \boxed{9.41 \frac{m}{s} \quad 80.63° \text{ South of West}}$

$\theta = \tan^{-1}\left(\frac{8 + 2\sin 40}{2\cos 40}\right) = 80.63°$

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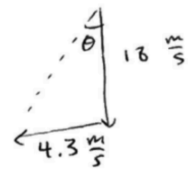
A15:

Given: distance = 51.6 km (from A1)
boat velocity = 18 $\frac{m}{s}$ due South
current = 4.3 $\frac{m}{s}$ due west




Required: Angle boat should head at to have shortest trip

Solve: Shortest trip = when boat travels straight across lake

Resultant velocity $= \sqrt{18^2 + 4.3^2} = 18.5$

$\theta = \tan^{-1}\left(\frac{4.3}{18}\right) = 13.44°$

If we try sending the boat due South, it will actually head 13.44° west of South due to ocean current

∴ To counteract the angle from the ocean current, the boat should be launched at angle 13.44° East of South

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A17.) *Radius not given – assume r = 1m*

Given: radius = 1 m
time = $\frac{\pi^2}{4}$ seconds

Required: Speed

Solve: Circumference of track $= 2\pi r = 2\pi(1m) = 2\pi$

Speed $= \frac{\text{distance}}{\text{time}} = \frac{2\pi}{\left(\frac{\pi^2}{4}\right)} = \frac{2\cancel{\pi}(4)}{\pi\cancel{^2}} = \frac{8}{\pi} = \boxed{2.55 \frac{m}{s}}$

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A19a:

Given: distance = 3 km
time = 100 s
final velocity = 0 (car came to stop)

Required: acceleration

Solve: Use kinematic equation $\Delta d = v_f \Delta t - \frac{1}{2} a \Delta t^2$

$$3000\text{m} = \cancel{0(100\text{s})} - \frac{1}{2} a (100)^2$$

$$a = \frac{3000}{-(\frac{1}{2})(100^2)} = \boxed{-0.6 \ \frac{m}{s}^2}$$

negative acceleration = deceleration
= slowing down

19b:

Given: distance = 3 km = 3000 m
$v_f = 0 \frac{m}{s}$ (car came to stop)
time = 100 s

Required: Initial velocity

Solve: Use kinematic equation $\Delta d = \left(\frac{v_f + v_i}{2}\right)\Delta t$

$$3000\text{m} = \left(\frac{0 + v_i}{2}\right)\Delta t$$

$$3000\text{ m} = \left(\frac{+v_i}{2}\right)(100\text{ s})$$

$$v_i = +\frac{(3000\text{ m})(2)}{100\text{s}} = 60 \frac{m}{s}$$

$\therefore$ Initial velocity is $60 \frac{m}{s}$ (in positive direction), final velocity is $0 \frac{m}{s}$

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A21a: Given: $g = 10 \frac{m}{s}$
$a = 2g = 20 \frac{m}{s}$
time in jet = 40s

Required: time to hit the ground

Solve: First we find how high up we are by using $\Delta d = v_0 t + \frac{1}{2} a t^2$
$v_0 = 0$ because jet started from rest so $\Delta d = \cancel{0t} + \frac{1}{2}(20 \frac{m}{s^2})(40s)^2$
so $\Delta d = 16000$ m

when you jump horizontally, your initial vertical velocity is 0

On your way down, your vertical acceleration is only due to $g$ so $a = 10\ \frac{m}{s^2}$ (downwards)

We can use $\Delta d = v_0 t + \frac{1}{2} a t^2$ again

$16000 = \cancel{0(t)} + \frac{1}{2}(10)t^2$ so $t = \sqrt{\frac{16000}{(\frac{1}{2})(10)}} = \boxed{56.57 \text{ seconds}}$

b.) Given: $t = 56.57$ seconds

$v_0 = 0$

$a = 10\ \frac{m}{s^2}$ (downwards)

Required: $v_f$

Solve: $v_f = v_0 + at = 0 + (10)(56.57) = \boxed{565.7\ \frac{m}{s} \text{ (downwards)}}$

A21c:

Given: Time jet is accelerating $= 40 + 56.57$ ← time while you are falling

Jet $v_0 = 0\ \frac{m}{s}$

Jet acceleration $= 2g = 20\ \frac{m}{s^2}$ (upwards)

Required: Distance between you & jet when you land (essentially, jet's vertical displacement)

Solve: $\Delta d = v_0 t + \frac{1}{2} a t^2 = \cancel{0t} + \frac{1}{2}(20)(40 + 56.57)^2$

$= \boxed{93257.65 \text{ m}}$

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A23:

Given: speed $= 100{,}000\ \frac{m}{s}$

Required: speed in $\frac{km}{hr}$

Solve: $\left(100{,}000\ \frac{\cancel{m}}{\cancel{s}}\right)\left(\frac{1\ km}{1000\ \cancel{m}}\right)\left(\frac{3600\ \cancel{s}}{1\ hr}\right) = \boxed{360{,}000\ \frac{km}{hr}}$

↖ your alien mom is <u>not</u> right

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**A25:** * Question should ask for acceleration in $\frac{m}{s^2}$ not $\frac{m}{s}$ *

Given: final speed $= \frac{350\ km}{hr}$

time = 2 minutes

Required: acceleration in $\frac{m}{s^2}$

Solve: speed $= \frac{350\ \cancel{km}}{\cancel{hr}}\left(\frac{1000\ m}{1\ \cancel{km}}\right)\left(\frac{1\ \cancel{hr}}{3600\ s}\right) = 97.22\ \frac{m}{s}$

time = 2 minutes = 120 s

Use equation $v_f = v_o + at \longrightarrow v_o = 0$ so $v_f = at$

$$a = \frac{v_f}{t} = \frac{97.22\ \frac{m}{s}}{120\ s} = 0.81\ \frac{m}{s^2}$$

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**A27a:**

Given: $v_i = 25.5\ \frac{m}{s}$ $v_f = 45\ \frac{m}{s}$ $d = 40\ m$ $t = X$

Required: Acceleration in terms of $X$ (time)

Solve: $v_f = v_o + at \longrightarrow 45\ \frac{m}{s} = 25.5\ \frac{m}{s} + aX$

$$a = \frac{45 - 25.5}{X} = \boxed{\frac{19.5}{X}\ \frac{m}{s^2}}$$

**A27b:**

We don't need any additional info; we can use equation $d = \left(\frac{v_i + v_f}{2}\right)t$ instead to solve for X, because we are given initial & final velocities and distance

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A29:

Given: $v_i = 8 \frac{km}{hr}$ $v_f = \frac{5km}{hr}$ $t = 5s$

Required: Deceleration & distance travelled during deceleration

Solve: $v_f = v_0 + at \longrightarrow a = \frac{v_f - v_0}{t} = \frac{5 km/hr - 8 km/hr}{5 \text{ seconds}}$ convert to $\frac{m}{s}$

$$= \frac{1.39 \frac{m}{s} - 2.2 \frac{m}{s}}{5 s}$$

$$= \boxed{-0.162 \frac{m}{s^2}}$$

negative = decelerating

$$\Delta d = \left(\frac{v_f + v_i}{2}\right)t = \left(\frac{1.39\frac{m}{s} + 2.2\frac{m}{s}}{2}\right)(5s) = \boxed{8.98 \text{ m}}$$

∴ You decelerated at $0.162 \frac{m}{s^2}$ & travelled 8.98m while decelerating

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A31:

Given: $v_i = 40 \frac{m}{s}$ $d = 500m$ (collision will occur in middle between them)

$v_f = 0$ (they come to a stop & avoid collision)

Required: Acceleration (deceleration) of each truck

Solve: $v_f^2 = v_i^2 + 2ad$ so $a = \frac{v_f^2 - v_i^2}{2d}$

$$= \frac{0 - 40^2}{2(500)}$$

$$= \boxed{-1.6 \frac{m}{s^2}}$$

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A33a:

While there is acceleration, the velocity of the ball while it falls the length of the window (a small distance) will be essentially constant. She can just divide the h (height of the window) by t (time to go from top of window to bottom) to get a roughly accurate measurement of how fast the ball was falling when it came to the window

A33b:

The ball's speed when you first drop it is $0 \frac{m}{s}$, acceleration is $9.8 \frac{m}{s^2}$ (downward), & she has a $v_f$ value from the calculation in A33a. She can use $v_f^2 = v_i^2 + 2ad$ to solve for d, which is how high above the window you were when you dropped it.

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A35:

Given: time = 5s  time to finish race = 36s  d = 2km = 2000 m

Required: Racer's top speed + acceleration

Solve: We have to assume the racer's 2 km occurs at top speed (no way to determine distance travelled during acceleration) so top speed = $\frac{2000m}{36s} = \boxed{55.56 \frac{m}{s}}$

Acceleration: $v_f = v_0 + at \longrightarrow a = \frac{v_f - v_0}{t} = \frac{55.56 \frac{m}{s} - 0 \frac{m}{s}}{5s}$

$= \boxed{11.1 \frac{m}{s^2}}$

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A37a:

Given: max impact velocity $= 15\,\frac{m}{s}$ (to be nonlethal) height $= 5m$ $g = 9.8\,\frac{m}{s^2}$

Required: actual impact velocity

Solve: $v_f^2 = v_o^2 + 2ad$

initial velocity $=0$

$$v_f = \sqrt{v_o^2 + 2ad} = \sqrt{0^2 + 2(9.8)(5)} = \boxed{9.9\,\frac{m}{s}}$$

∴ The bird will survive

A37b:

Given: height $= 15m$

Required: Actual impact velocity

Solve: We use same formula as A37a

$$v_f = \sqrt{v_o^2 + 2ad} = \sqrt{0^2 + 2(9.8)(15)}$$

$$= \boxed{17.15\,\frac{m}{s}}$$

∴ The bird will die

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A39a:

Given: initial velocity $= 11.5\,\frac{m}{s}$

deceleration : $1\,\frac{m}{s^2}$

Required: function for displacement during deceleration and function for speed after $X$ seconds

Solve: For displacement: $d = v_o t + \frac{1}{2}at^2$

$$= 11.5(x) + \frac{1}{2}(-1)(x^2)$$

$$\boxed{d = 11.5x - \frac{1}{2}x^2}$$

For speed after x seconds: $v_f = v_o + at$

$= 11.5 + (-1)x$

$\boxed{v_f = 11.5 - x}$

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A41. Given:

$V_o = 0 \quad V = 15\,km/h$

$X_o = 0 \quad X = 0.15\,km$

Asked For:

$\Delta t = ?$

Formula:

$$\Delta x = \left(\frac{V + V_o}{2}\right) t$$

Work:

$$x - \cancel{x_o} = \left(\frac{V + \cancel{V_o}}{2}\right) t$$

$$0.15\,km = \left(\frac{15\,km/h}{2}\right) t$$

$$\frac{2(0.15\,km)}{15\,km/h} = t$$

$$\frac{0.30\,\cancel{km}}{15\,\cancel{km}/h} = t$$

$$t = 0.02\,hrs \times 60\,\frac{min}{hr} = 1.2\,min$$

∴ it takes the flamingo 0.02 hrs or 1.2 min to accelerate.

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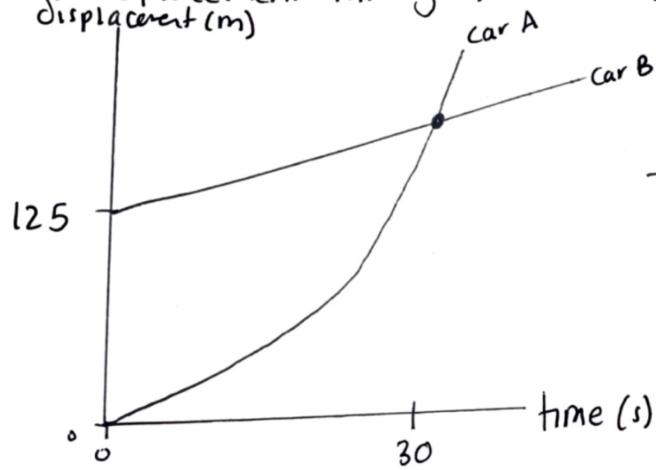
A43.

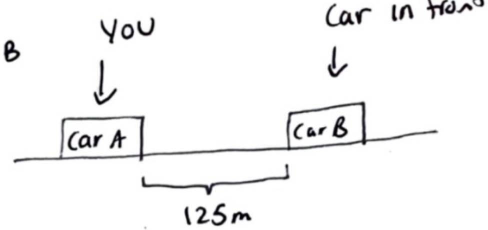
a)

$$V = \frac{30\,m}{s} \cdot \frac{3600\,s}{hr} \cdot \frac{km}{1000\,m} = 108\,km/hr$$

b) displacement-time graph:




Visual of situation:




Equations:

Car A (constant acceleration) Car B (constant velocity)

* t is a common parameter

When $t=30$
$X_A = X_B$

(1)
$$X_A = \cancel{X_{0A}}^{0} + V_{0X_A}t + \frac{1}{2}a_A t^2$$
$$X_A = 30t + \frac{1}{2}(a_A)t^2$$

$$X_B = X_{0B} + V_{0XB}t$$
(2)
$$X_B = 125 + 30t$$

$$\cancel{30(30)} + \frac{1}{2}a_A(30)^2 = 125 + \cancel{30(30)}$$
$$\frac{450\,a_A}{450} = \frac{125}{450}$$
$$a_A = 0.27\bar{7}\ m/s^2$$
$$= 0.28\ m/s^2$$

∴ Car A accelerates at a constant $0.28\ m/s^2$.

c) Formula:

$$V^2 - V_0^2 = 2a\Delta X$$

Asked For:

$V = ?$

* Need $\Delta X$, can use equation (1) or (2) from part b

$$V^2 - (30)^2 = 2(0.2778)(1025m)$$
$$V^2 = 569.449 + 900$$
$$V = \sqrt{1469.449}$$
$$V = 38.327\ m/s$$
$$V = 38\ m/s$$

(1)
$$X_A = 30t + \frac{1}{2}a_A t^2$$
$$X_A = 30(30) + \frac{1}{2}(0.2778)(30)^2$$
$$= 900 + 125.001$$
$$\approx 1025m$$

∴ the speed of car A when it has caught up to car B is 38 m/s.

A45. Given:

+y ↑

$y_{max} = ?$ $V_{y\,max} = 0$

Asked For:

$t_{total} = ?$

$a = -9.80\,m/s^2$

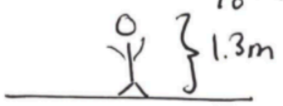
Formulas:

(1) $V_{y\,max} = V_0 + at$

(2) $y_{max} = y_0 + V_0 t + \frac{1}{2}at^2$

(3) $t_{fall} = \sqrt{\frac{2d}{g}}$ *Let $d = y_{max}$

$y_0 = 1.3\,m$ $V_0 = 120\,m/s$




Work:

(1) $\cancel{V_{y\,max}}^{0} = \cancel{V_0}^{120\,m/s} + at$

$\frac{-120\,m/s}{-9.80\,m/s^2} = \frac{(-\cancel{9.80\,m/s^2})\,t}{-\cancel{9.80\,m/s^2}}$

$t = 12.245\,s$ time to get from childs hands to highest point

(2) $y_{max} = y_0 + V_0 t + \frac{1}{2}at^2$

$= 1.3\,m + (120\,m/s)(12.245\,s) + \frac{1}{2}(-9.80\,m/s^2)(12.245\,s)^2$

$= 1470.7\,m - 734.106\,m$

$= 736.59\,m$ ← max height achieved by rock

(3) $t_{fall} = \sqrt{\frac{2\,y_{max}}{g}}$

$= \sqrt{\frac{2(736.59\,m)}{9.80\,m/s^2}}$ time to get from max height to ground

$= 12.261\,s$

$t_{total} = 12.245\,s + 12.261\,s$

$= 24.5\,s$

$\approx 25\,s$ (2sd)

∴ it takes 25 s or 24.5 s for rock to go up and come down!

A47. Given:

+y

$Y_0 = \frac{1}{3}h$

$Y = 0$

$\Delta t = 2s$

$a = -9.80\,m/s^2$

$V = 0$

Asked For:

$h = ?$

Formula:

$\Delta y = \cancel{\mathring{V}\Delta t} - \frac{1}{2} a\Delta t^2$

$0 - \frac{1}{3}h = -\frac{1}{2}(9.80\,m/s^2)(2s)^2$

$\frac{1}{3}h = \frac{1}{2}(-9.8\,m/s^2)(4s^2)$

$\frac{h}{3} = -19.6\,m$

$1H = 58.8\,m$

* Assume gameboy's final velocity is zero

$\therefore$ the house is 58.8m or approximately 60 m tall.

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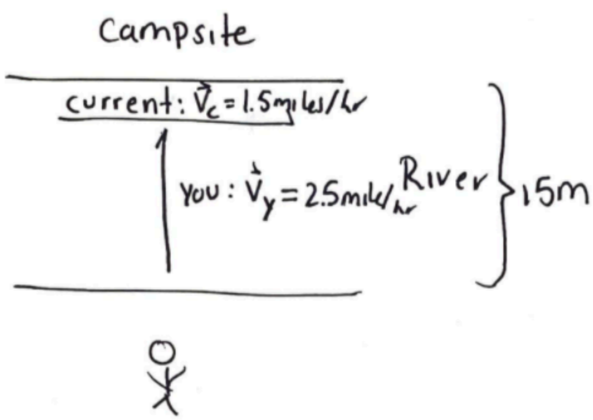
A49.

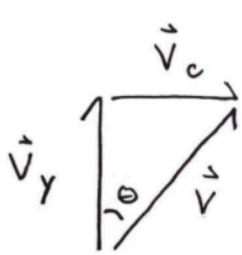



Let $\vec{V}_c$ denote velocity of current

Let $\vec{V}_y$ denote velocity of you in canoe

Let $\vec{V}$ denote actual velocity vector

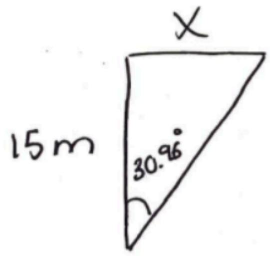
a) if canoe trip is $\perp$ to river, how far does camper end up?




SOH CAH TOA

$\tan\theta = \frac{opp}{adj}$

$\theta = \tan^{-1}\left(\frac{\vec{V}_c}{\vec{V}_y}\right) = \tan^{-1}\left(\frac{1.5\,miles/hr}{2.5\,miles/hr}\right) = 30.96^\circ$



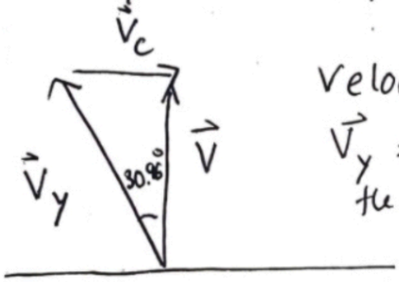

$$\tan(30.96^\circ) = \frac{x}{15m}$$

$$x = 8.998\ m$$

$$x = 9.0\ m$$

$\therefore$ you end up 9.0m downstream if you canoe perpendicular to the bank.

b) can be solved intuitively using question a's answer:
If current reroutes you at an angle of 30.96° to the right of the perpendicular (assuming current flows from left to right) by rowing 30.96° to the left you should end up directly across from your initial position!




Velocity upstream is likely referring to $\vec{V}_y = 2.5$ miles/hr at an angle of 30.96° from the normal.

Also, $\vec{V}$ can be found using Pythagorean theorem: $a^2 + b^2 = c^2$

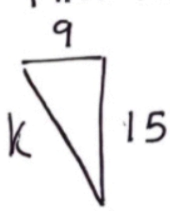
$$(\vec{V}_y)^2 = (\vec{V}_c)^2 + (\vec{V})^2$$

$$(2.5)^2 - (1.5)^2 = \vec{V}^2$$

$$\vec{V} = 2.0\text{ miles/hr}$$

$v = 2.5$ miles/hr $= 1.1176$ m/s

c) First need to calculate distance taken by canoe: ($k$)




$$k^2 = 9^2 + 15^2$$

$$k = \sqrt{306}$$

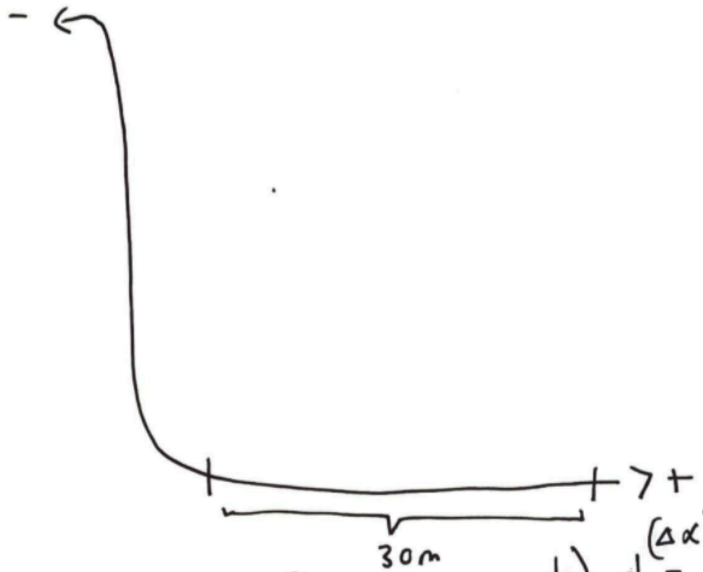
$$k = 17.49\ m$$ ← distance

$$V = \frac{\Delta d}{\Delta t} = \frac{17.49m}{\Delta t} = 1.1176 m/s$$

$$\Delta t = 15.6\ s$$

$\therefore$ it takes 15.6s to cross the stream.

A51. * Assume Part a refers to a complete drop




a)

$a = 6.6\,m/s^2$

$v_0 = 0$

$V = 65\,km/h = 18.0556\,m/s$

$\Delta t = ?$

$a = \dfrac{\Delta v}{\Delta t}$

$a = \dfrac{V - V_0}{\Delta t}$

$\Delta t = \dfrac{V - V_0}{a}$

$= \dfrac{18.0556\,m/s}{6.6\,m/s^2}$

$= 2.7357\,s$

$= 2.7\,s$

$\therefore$ the cart reaches max velocity in 2.7 s.

b) $d\ (\Delta x) = 30\,m$

$V_0 = 18.0556\,m/s$

$V = 0$

$a = ?$

$V^2 - V_0^2 = 2a\Delta x$

$a = \dfrac{\cancel{V^2} - V_0^2}{2\Delta x}$

$= \dfrac{-(18.0556\,m/s)^2}{2(30\,m)}$

$= -5.433\,m/s^2$

$= -5.4\,m/s^2$

$\therefore$ the cart accelerates at $-5.4\,m/s^2$ or decceleates at $5.4\,m/s^2$.

c) $\Delta t = ?$

$$\Delta x = \left(\frac{V + V_0}{2}\right)t$$

$$\frac{2(30m)}{18.0556m/s} = t$$

$t = 3.323\ s$

$t = 3.3\ s$

$\therefore$ it takes the cart 3.3 s to stop.

d) According to Newton's $2^{nd}$ law $F = ma$, acceleration and mass are inversely proportional.
$\therefore$ if the mass was doubled the acceleration would be halved.

$$m \propto \frac{1}{a}$$

---

A53.

(total time)
$\Delta t = ?$


$X_0 = 0$
$V_0 = 2m/s$

$X_1 = 2m$
$V_1 = 0$

$X = 5m$
$V = 4m/s$

$a_1 = -1m/s^2$

$a_2 = ?$

$$a_1 = \frac{\Delta V}{\Delta t}$$

$$a_1 = \frac{V_1 - V_0}{\Delta t}$$

$$\Delta t = \frac{-2m/s}{-1m/s^2}$$

$$\Delta t = 2\ s$$

$$V^2 - V_0^2 = 2a\Delta x$$

$$a_2 = \frac{V^2 - V_0^2}{2\Delta x}$$

$$a_2 = \frac{(4m/s)^2 - 0}{2(3m)}$$

$$a_2 = 2.667\ m/s^2$$

$$t_{total} = 2\,s + 1.5\,s$$
$$= 3.5\,s$$

$\therefore$ the total time for the sequence of motions is 3.5 s

$$a_2 = \frac{\Delta V}{\Delta t}$$
$$\Delta t = \frac{V - V_1}{a_2}$$
$$= \frac{4\,m/s}{2.667\,m/s^2}$$
$$= 1.499\,s$$

---

A55. Visual of the situation:


$x = ?$ $\quad x_0 = 0$

$V = 5.0\,m/s$ $\quad V_0 = 0$

$a = 0.5\,m/s^2$

a) Formula: $V^2 - \cancel{V_0^2} = 2a\Delta x$

$$(5.0\,m/s)^2 = 2(0.5\,m/s^2)\Delta x$$
$$\Delta x = 25\,m$$

b) Crocodile is constantly moving at 2 m/s
need to calculate time it takes for duck to start flying

$$V = \cancel{V_0} + at$$
$$t = \frac{V}{a}$$
$$t = \frac{5.0\,m/s}{0.5\,m/s^2}$$
$$t = 10\,s$$

$\therefore$ it takes the duck 10 s to start flying, in that time the duck travels 25 m while the crocodile travels 20 m, even if the crocodile is right beside duck to begin the duck will still get away!

$$d = t \cdot V$$
$$= (10\,s)(2\,m/s)$$
$$= 20\,m$$

---

A57.

✱ Assume 20° off the ground


$$\text{Range, } R = \frac{v_0^2 \sin 2\theta}{g}$$

$V_0 = ?$
$\theta = 20°$
$R = 640m\ (x_f - x_0)$
$g = 9.80m/s^2$

$$\frac{(640m)(9.80m/s^2)}{\sin(2 \cdot 20°)} = V_0^{\ 2}$$

$$\sqrt{9757.4998m^2/s^2} = V_0$$

$$V_0 = 98.78m/s$$

$$V_0 = 99\ m/s$$

∴ the inital velocity of the ball is 99 m/s assuming the ball is hit such that it comes off the ground at an angle of 20°.

---

A59. Given the information provided the only applicable acceleration to consider would be due to gravity and be directed downwards.

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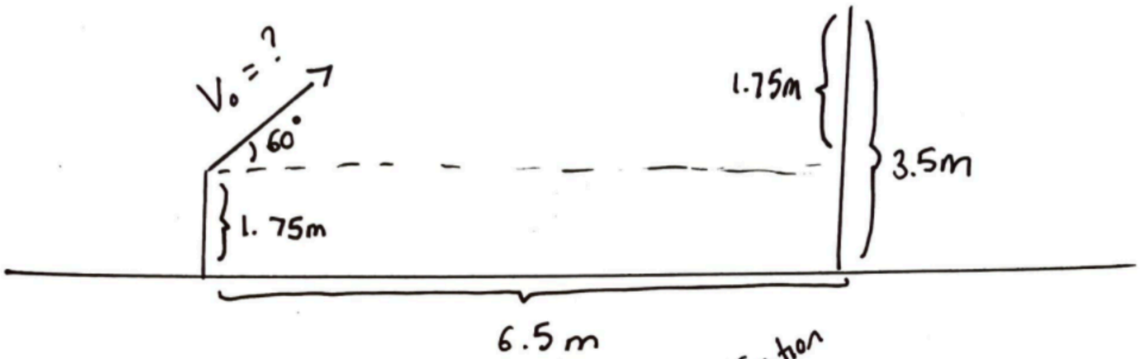
A67.




$\underline{x\text{-dir}}$

$X_0 = 0$

$X = 6.5m$

$V_{0x} = V_0 \cos 60°$

(1)

$X = \cancel{X_0}^{0} + V_{0x} t$

$6.5m = V_0 \cos 60° \cdot t$

$t = \dfrac{6.5m}{V_0 \cos 60°}$

$\underline{y\text{-dir}}$

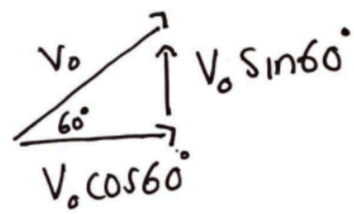
$Y_0 = 0$

$Y = 1.75m$

$a = -9.80 m/s^2$

$V_{0y} = V_0 \sin 60°$

simplification




(2)

$Y = \cancel{Y_0}^{0} + V_{0y} t + \frac{1}{2} a t^2$

* t is a common Parameter

$1.75m = \cancel{V_0} \sin 60° \cdot \dfrac{6.5m}{\cancel{V_0} \cos 60°} + \frac{1}{2}(-9.8 m/s^2) \dfrac{6.5m}{V_0 \cos 60°}$

$1.75m = \tan 60° (6.5m) - 4.9 m/s^2 \cdot \dfrac{6.5m}{V_0 \cos 60°}$

$-9.508 = \dfrac{-31.85}{V_0 \cos 60°}$

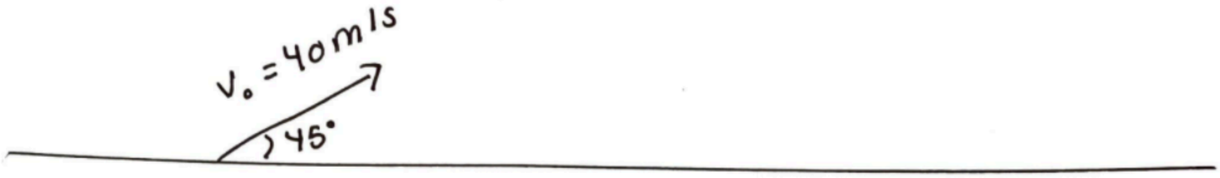
$\dfrac{-4.754\, V_0}{4.754} = \dfrac{-31.85}{-4.754}$

$V_0 = 6.7 m/s$

∴ the inital speed of the basketball was 6.7 m/s.

A63.

*Note that $x = 150m$ and $y = 15m$ are not the final Posistion of the ball just requared for comparison at the end




$$R = \frac{V_0^2 \sin(2\theta)}{a}$$

$$= \frac{(40m/s)^2 \sin(2 \cdot 45°)}{9.80m/s^2}$$

$$= 163.3m$$

$$h = \frac{V_0^2 \sin^2(\theta)}{2g}$$

$$= \frac{(40m/s)^2 \sin^2(45°)}{2(9.80m/s^2)}$$

$$= \frac{1600 m^2/s^2 \cdot (\frac{1}{2})}{19.6m/s^2}$$

$$= 40.8m$$

Final position of Ball:

$(\overset{x}{163.3m}, \overset{y}{40.8m})$

∴ the baseball player exceeds the 'Out of the park' target of (150m, 15m) and actually ends up at (163.3m, 40.8m) which is 13.3 m further in the x-dir and 25.8m in the y-dir.

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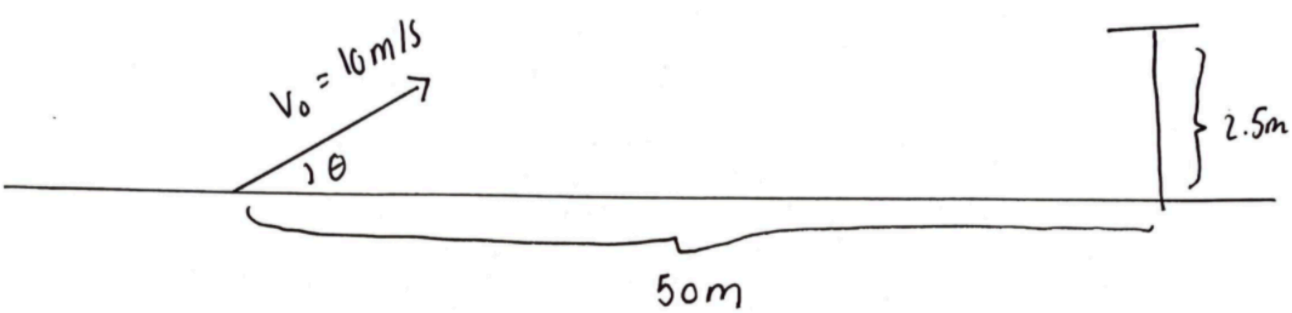
A65.



$$h = \frac{V_0^2 \sin^2\theta}{2g}$$

$g = 9.80 m/s^2$
$V_0 = 10 m/s$
$h = 2.5 m$

$$2hg = V_0^2 \sin^2\theta$$

$$\frac{2hg}{V_0^2} = \sin^2\theta$$

$$\frac{2(2.5m)(9.80m/s^2)}{(10m/s)^2} = \sin^2\theta$$

$$\sqrt{\sin^2\theta} = \sqrt{0.49}$$

$$\sin\theta = 0.7$$

$$\theta = \sin^{-1}(0.7)$$

$$\theta = 44.4^\circ$$

∴ the angle at which the ball is kicked is 44°.

---

A67. $$T = \frac{2u\sin\theta}{g}$$

* Assume the child is firing water gun directly upward ($\theta = 90^\circ$)

$$T = \frac{2u}{g}$$

T - time of flight = 4 s

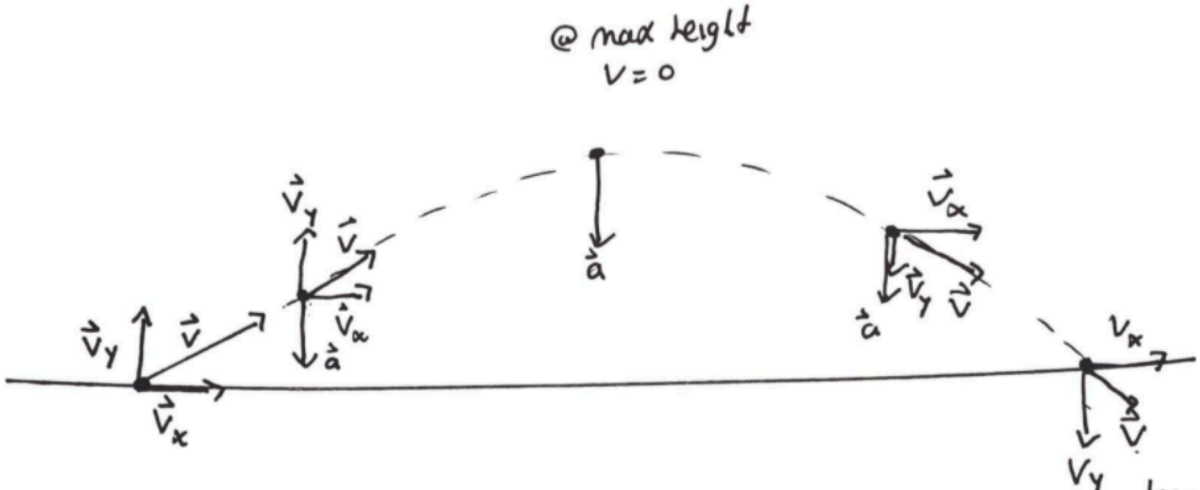
$$\frac{4s\,(9.8m/s^2)}{2} = \frac{\cancel{2}u}{\cancel{2}}$$

$u = 19.6 m/s$ or $20 m/s$

∴ the inital speed of water out of the water gun is 20 m/s.

---

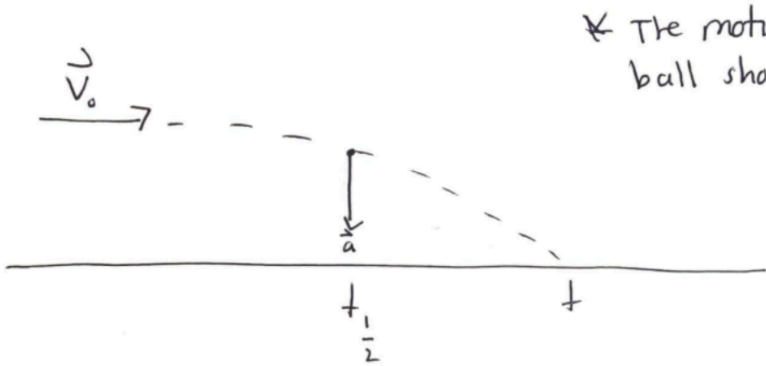
A69.




As you can see from the diagram velocity can be broken up into an x-component and a y-component. The y-comp is parrallel to acceleration except when at max height as velocity is zero. The x-component is perpendicular throughout. However, the vector sum of the x-comp and y-comp is neither parallel or perpendicular with acceleration throughout the parabolic motion.

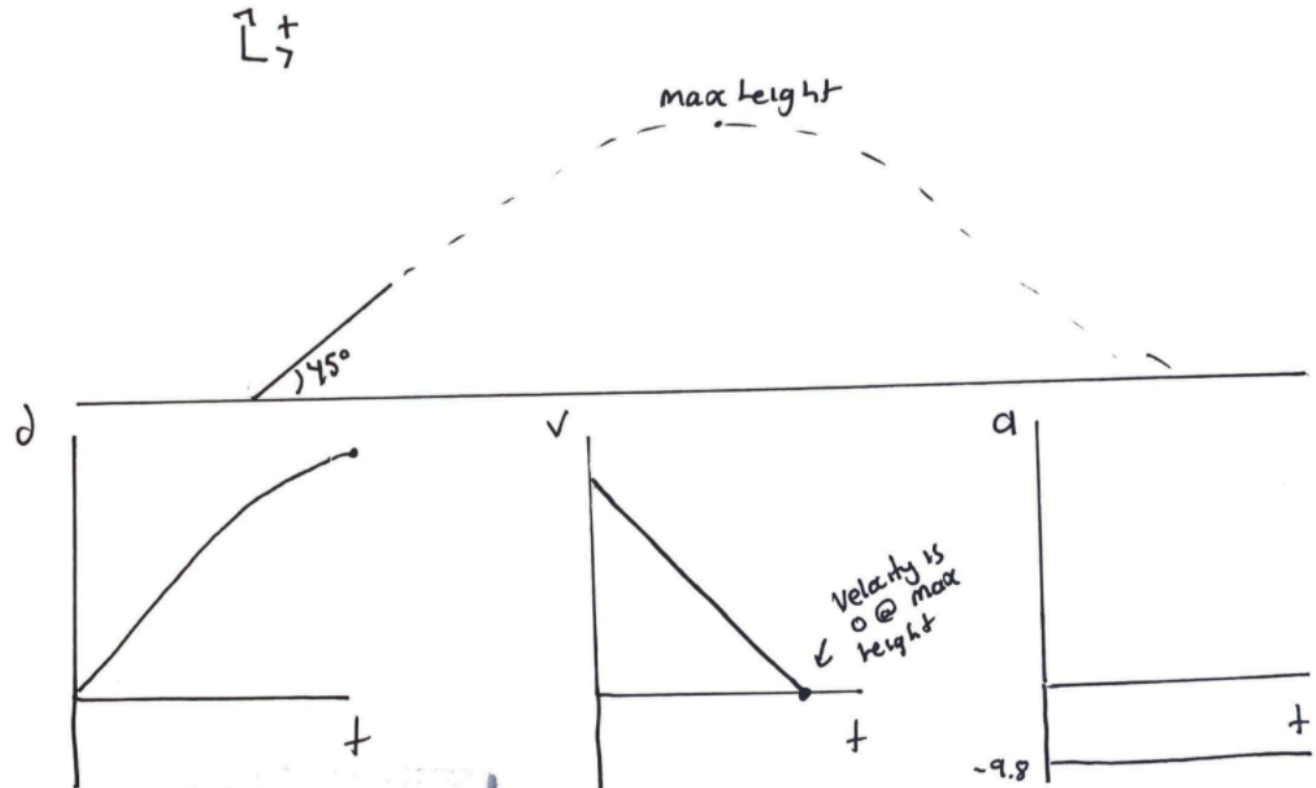
---

A71. Considering acceleration is constant in y-direction and velocity is constant in x-direction at time $t_{\frac{1}{2}}$ the acceleration vector should be directly downward.




* The motion of the ball should be parabolic

A73.




inverted Parabola

* graphs only illustrate before max height