THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES
DEPARTMENT OF PHYSICS

PH 110 INTRODUCTORY PHYSICS

TUTORIALSHEET 3_2023: Kinematics

1. A ball thrown vertically upward is caught by the thrower after 2.5 s. Find (a) the initial speed of the ball and (b) the maximum height the ball reaches.

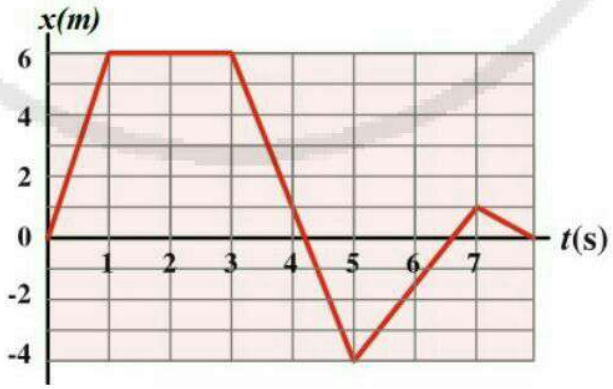
2. A bullet in a riffle accelerates uniformly from rest at $a = 70000\,\mathrm{m/s^2}$. If the velocity of the bullet as it leaves the muzzle is $a = 70000\,\mathrm{m/s^2}$, how long is the rifle barrel? How long did it take for the bullet to travel the length of the barrel? What is the average speed of the bullet?

3. A red car is stopped at a red light. As the light turns green, it accelerates forward at 2 $\mathrm{m/s^2}$. At the exact same instant, a blue car passes by traveling at 62 km/h. When and how far down the road will the cars again meet? Sketch the d versus t motion for each car on the same graph. What was the average velocity of the red car for this time interval? For the blue car? Compare the two and explain the result?

4. A cyclist, starting from rest, accelerates at 0.30 $\mathrm{ms^{-2}}$ from t = 0.0 s until t = 5.0 s, then travels at a constant velocity until t = 7.0 s, and finally comes to rest in 3.0 m

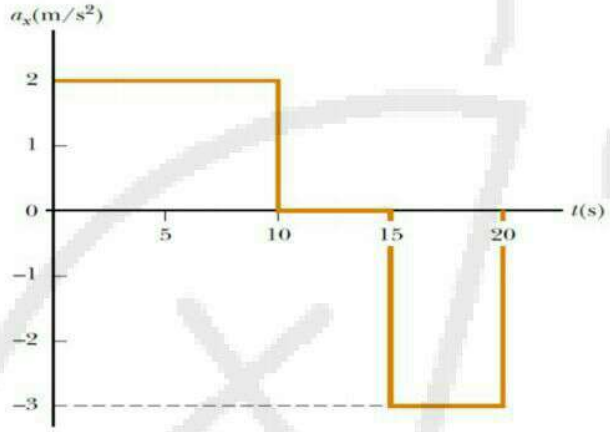
   a. Calculate her velocity at the end of 5.0 s.
   b. Calculate her displacement between 0.0 s and 7.0 s.
   c. Calculate her acceleration as she comes to rest.

5. An object's motion along the x-axis is represented by the following figure



(a) Find the average velocity of the object during the period of 8 seconds shown.
(b) Plot the object's velocity versus the time period shown.
(c) Plot the distance covered by the object versus the time.
(d) Find the average speed of the object for the period shown.

6. A particle starts from rest and accelerates as shown in the figure below.
   (a) Find the particle's speed at t = 10 s and at t = 20 s.
   (b) Draw the velocity-time graph for a particle in the interval from t=0 to t=20s.
   (c) Determine the distance traveled in the first 20 seconds.



7. Two parallel rail tracks run north-south. Train A moves north with a speed of 54 km/h and train B moves south with a speed of 90 km/h. What is the relative velocity in m/s of
   (a) B with respect to A
   (b) the ground with respect to B
   (c) a monkey running on the roof of train A against its motion (with velocity 18 km/h with respect to A) as observed by a man standing on the ground.

8. A particle moves along the x axis according to the equation:

$$x = 2 + 3t - t^2$$

where x is in m and t is in s. At $t = 3s$, find (a) the position of the particle, (b) its velocity, and (c) its acceleration.

9. The position of the ball tossed vertically upwards is described by the equation:

$$y = 7t - 4at^2$$

where y is in metres and t is in seconds. Find (a) the initial velocity at $t_0 = 0$, (b) the velocity at $t_0 = 1.26s$, and (c) the acceleration of the ball.

10. A projectile is fired with an initial speed of 114 m/s at an angle of 60 ° above the horizontal from the top of a cliff 49 m high.
Find:
(a) the time to reach the maximum height,
(b) the maximum height,
(c) the total time in the air,
(d) the horizontal range and
(e) the components of the final velocity just before the projectile hits the ground.

11. Two stones are dropped from the edge of a 60m cliff, the second stone 1.6s after the first. How far below the top of the cliff is the second stone when the separation between the two stones is 36m?

12. A ball thrown from the top of a 50m tall building is given an initial velocity of 20m/s straight upwards. The ball just misses the edge of the roof on its way down.
a) Determine the time at which the ball reaches its maximum height.
b) Determine the maximum height.
c) The time at which the ball returns to the height from which it was thrown.
d) The velocity of the ball at this instant.
e) The velocity and position of the ball at $t = 5$s.

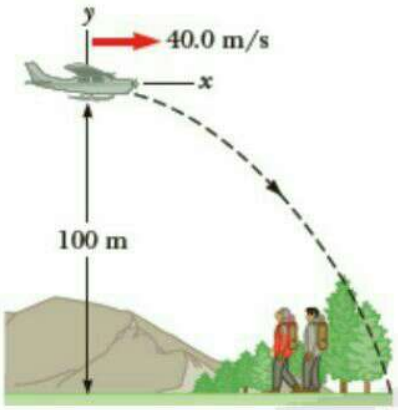
13. A stone is released from a hot- air balloon which is rising steadily at 4m/s. Find the velocity of the stone after 3 s of release.

14. A stone is dropped by a person from the top of a building, which is 200 m tall. At the same time, another stone is thrown upwards, with a velocity of 50 m/s by a person standing at the foot of the building. Find the time after which the two stones meet.

15. Show that time of ascent of an object thrown vertically upwards is equal the time of its descent.

16. A bullet is fired from the ground vertically upwards with an initial velocity of 100 m/s.
(i) Find the total time of flight.
(ii) Find the total distance covered by the bullet.
(iii) What is the bullet's velocity on the ground?
(iv) What are the assumptions made in these calculations?

17. An Alaskan rescue plane drops a package of emergency rations to stranded hikers, as shown in the Figure below. The plane is traveling horizontally at 40.0 m/s at a height of 1.0×10^2 m above the ground. Neglect air resistance.

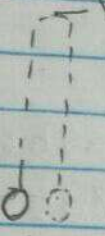


a) Where does the package strike the ground relative to the point at which it was released?
b) What are the horizontal and vertical components of the velocity of the package just before it hits the ground?
c) What is the angle of the impact?

(1. a) data

$t = 2.5s$

$g = -9.8 m/s^2$



$t = 1.25_s$

$V = u + at$

$V_F = V_0 + gt$

$0 = V_0 + (-9.8)(1.25)$

$0 = V_0 - 12.25$

$V_0 = 12.25 m/s$

(b.) You can use $s = ut + \frac{1}{2}at^2$ or $v^2 = v_0^2 + 2as$ but with the first one get half the time (1.25_s).

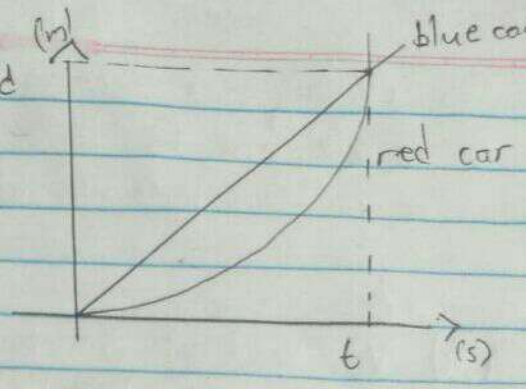
$s = V_0 t + \frac{1}{2} g t^2$

$s = (12.25)(1.25) + \frac{1}{2}(-9.8)(1.25)^2$

$= 15.3125 - 7.65625$

$s = 7.66m$

3 To draw a diagramatic sketch of the two cars we need to know that the graph for uniform acceleration is a curve going upwards in a d versus t motion and constant velocity is a slant slope.



(a) when they meet $S_{red} = S_{blue}$

using the formular $S = ut + \frac{1}{2}at^2$

$S_{red} = S_{blue}$

$V_{o_{red}} t_{red} + \frac{1}{2} a t_{red}^2 = V_{o_{blue}} t_{blue} + \frac{1}{2} a t_{blue}^2$

but from the sketch graph there t is the same therepore, replace t_{red} and t_{blue} with t jxt.

$V_{o_{red}} t + \frac{1}{2} a t^2 = V_{o_{blue}} t + \frac{1}{2} a t^2$

$(0) t + \frac{1}{2}(2) t^2 = (17.2 m/s) t + \frac{1}{2}(0) t^2$

$\frac{t^2}{t} = \frac{17.2t}{t}$

$t = 17.2s$

distance.

$S_{red} = V_{o_{red}} t_{red} + \frac{1}{2} a t_{red}^2$

$= (0)(17.2) + \frac{1}{2}(2)(17.2)^2$

$S = 295.8m$

average velocity $= \frac{\text{total distance}}{\text{total time taken}}$

$= \frac{295.8m}{17.2s}$

$= 17.2 m/s$

(b) there average velocity would

be the same because the two cars covered the same distance in the same time interval

d $v_f = v_0 + at$

$v_f = 0 + (0.3)(5)$

$v_f = 1.5 m/s$

(b.) After 5s the car has two phases.

Phase 1

$s = ut + \frac{1}{2}at^2$

$s = (0)(5) + \frac{1}{2}(0.3)(5)^2$

$s = 3.75m$

Phase 2

$s = ut + \frac{1}{2}at^2$

$s = (1.5)(2) + \frac{1}{2}(0)(2)^2$

$s = 3m$

$\therefore$ total displacement $= 3.75 + 3$

$= 6.75m$

c. Graph

$v^2 = u^2 + 2as$

$0^2 = (1.5)^2 + 2a(3)$

$-2.25 = 6a$

$a = -0.375 m/s^2$

5 $V = \frac{\Delta d}{\Delta t} = \frac{0}{8s} = 0\ m/s$

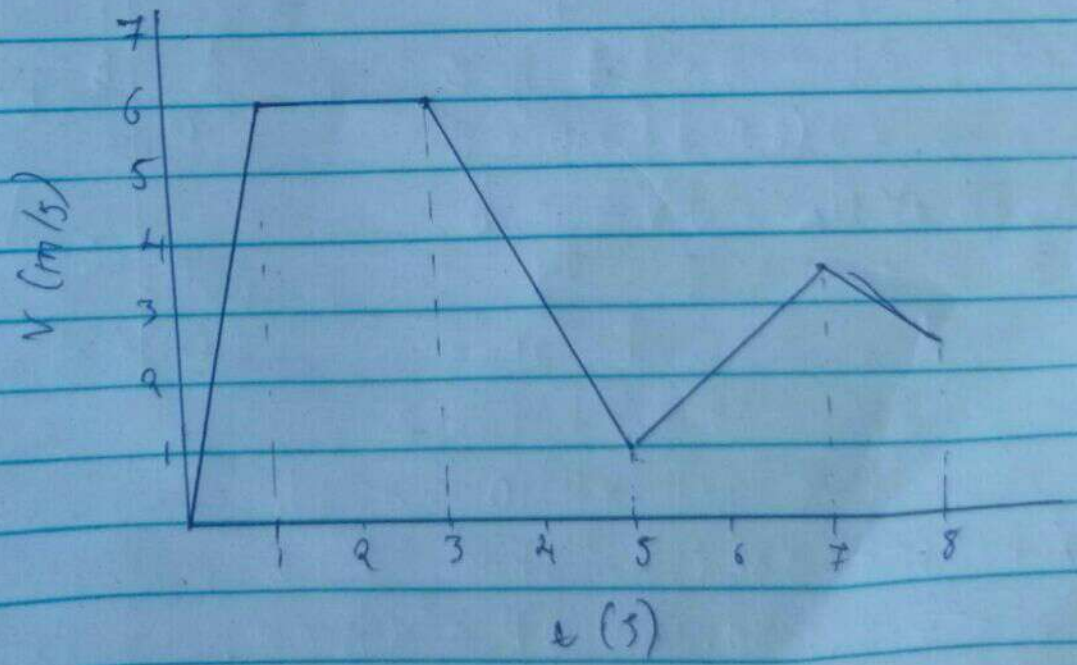
b To plot the velocity versus time graph, we need to know how the velocity is changing with respect to the distance and time.

using $v = \frac{\Delta x}{\Delta t}$

① $v = \frac{6}{1} = 6\ m/s$ ② $v = \frac{0}{2} = 0\ m/s$ ③ $v = \frac{-10}{2} = -5\ m/s$

④ $v = \frac{5}{2} = 2.5\ m/s$ ⑤ $v = \frac{-1}{1} = -1\ m/s$

If you want to be smart think like a smart person !!!



(b.) ave speed = $\frac{\text{total distance covered}}{\text{Yonse time taken!}}$

toto distance = $\frac{1}{2}bh + cb + \frac{1}{2}(a+b)h + \frac{1}{2}(a+b)h + \frac{1}{2}(a+b)h$

so ati someone out there is confused .... lol, ba family pillar kosemi !!!

area under the graph

total distance = $A_1 + A_2 + A_3 + A_4 + A_5$

$= \frac{1}{2}(1)(6) + (2\times6) + \frac{1}{2}(1+6)2 + \frac{1}{2}(1+3.5)2 + \frac{1}{2}(2.5+3.5)\cdot1$

$= 3 + 12 + 7 + 4.5 + 3$

$= 29.5\text{m}$

$\therefore$ average speed = $\frac{29.5}{8}$

average speed = 3.69m/s

6 (2 mks) Area under the graph of a vs t give change in velocity ΔV

∴ from 0s to 10s

$\Delta v = 2 \times 10$

$\Delta V = 20 m/s$

since its speed at $V_0 = 0s$ we say

$\Delta V = V_F - V_0$

$V_F = \Delta V + 0$

$V_F = 20 m/s$

(2 mks) Between $t = 15s$ and $t = 20s$, the area is

$\Delta V = (-3 \times 5)$

$= -15 m/s$

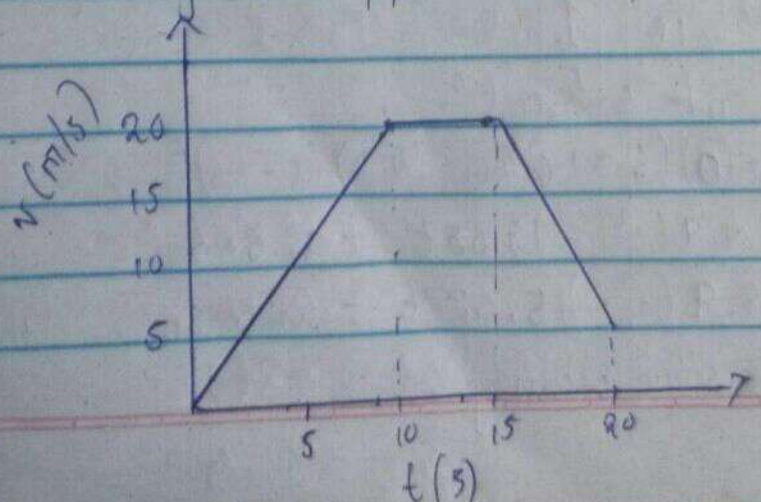
∴ between $t = 0s$ and $t = 20s$ the velocity is

$\Delta V = 20 + 0 + (-15)$

$\Delta v = 5 m/s$

∴ velocity at $t = 20s = 5 m/s$

b (2 mks) Using the information pa mulu we can draw this



c distance can be found by area under the graph

$A_1 = \frac{1}{2}bh \quad A_2 = lb \quad A_3 = \frac{1}{2}(a+b)h$

$= \frac{1}{2}(10)(20) + (20 \times 5) + \frac{1}{2}(5+20)5$

$d = 262.5m$

7. $V_{BA} = V_B + V_A$

$= 25 + 15$

$V_{BA} = 40 m/s$

$54 km/h = 15 m/s$

$90 km/h = 25 m/s$

$18 km/h = 5 m/s$

(b) $V_{GB} = V_G -$

$= 25 m/s$

(c) $V_{mA} = V_m - V_A$

$5 = 15 - V_m$

$V_m = 15 - 5$

$V_m = 10 m/s$

(8) $x = 2 + 3t - t^2$

(a) $x = 2 + 3(3) - (3)^2$

$x = 2m$

$x = 2 + 3t - t^2$

(b.) $v = 3 - 2t$

$v = 3 - 2(3)$

$v = -3 m/s$

9.

Tefyonse basanga boi!!
some questions are for the gods!!

For Q.10 the velocity ought to be 11.4m/s
Herriway, Mwakwete 6 points 50 jx7
plug in 11.4m/s as you solve
and follow the same steps!!

Question 10

DATA

x motion

$x = ?$

$V_{0x} = 113 \cos 60°$

$V_{0x} = V_{Ax} = V_{Bx}$

y - motion

$y_B = -49m$

$V_{0y} = 113 \sin 60°$

$V_{Ay} = 0$

$a_y = -9.8 m/s^2$

(a)

$V_y = V_{iy} + gt_1$

$t_1 = \dfrac{V_{fy} - V_{iy}}{g}$

$= \dfrac{0 - 113 \sin 60°}{-9.8}$

$= 9.99_s$

(b) $y = V_{iy}t + \frac{1}{2}gt^2$

$y = 113 \sin 60° (9.99) - \frac{1}{2}(9.8)(9.99)^2$

$y = 489m$

③ finding the total time in the air

$$Y = V_{iy} + \frac{1}{2} a_y t_2^2$$

$$-49m = (113 \sin 60) t_2 - \frac{1}{2}(9.8) t^2$$

$$-49m = 97.97 - 4.9 t^2$$

$$4.9t^2 - 97.9t - 49 = 0$$

$$t_2 = 20.5 \text{ s} \qquad t = -0.49 \text{ s}$$

We reject the second solution (it gives the time the projectile would have hit the ground, if it had been thrown from there)

④ Find the horizontal range (x_R)

$$V_f^f = V_i t + \frac{1}{2} g t^2$$

$$= (113 \cos 60)(20.5) = -103 \text{ m}$$

⑤ find the components of the final velocity

$$V_{fy} = V_{iy} + gt$$

$$= 113 \sin 60 - 9.8(20.5)$$

$$= \underline{-103 \text{ m/s}}$$

$$V_{fx} = V_{ix} = 113 \cos 60 = \underline{56.5 \text{ m/s}}$$

DATA

Stone 1

$u = 0 m/s$

$t = t$

$a = 9.81 m/s^2$

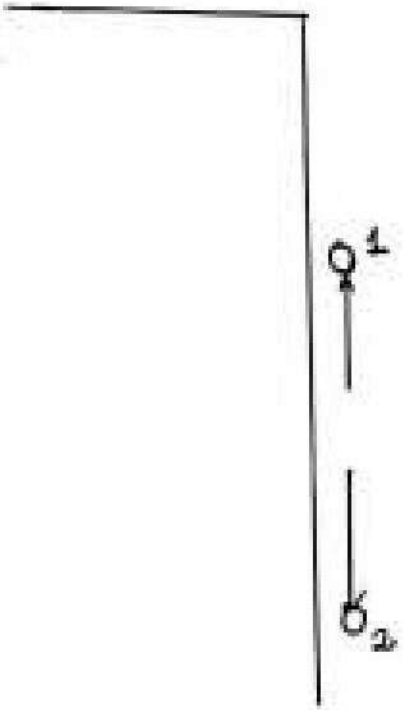
Stone 2

$u = 6 m/s$

$t = t - 1.6$

$d = d - 36$

$a = 9.8 m/s$



For Stone 1

$$d = u_1 t + \frac{1}{2} a t^2$$

$$d = 0 + \frac{1}{2}(9.8) t^2$$

$$d = 4.9 t^2 \quad \ldots \ldots \textcircled{1}$$

Stone 2

$$d - 36 = ut + \frac{1}{2} a t^2$$

$$d - 36 = \frac{1}{2}(9.8) t^2$$

$$d - 36 = 4.9 (t - 1.6)^2$$

$$d - 36 = 4.9 (t^2 - 3.2t + 2.56)$$

$$d - 36 = 4.9 t^2 - 15.7t + 12.5$$

$$d = 4.9 t^2 - 15.7t + 12.5 + 36$$

$$d = 4.9 t^2 - 15.7t + 48.5 \quad \ldots \ldots \textcircled{2}$$

$$4.9 t^2 = 4.9 t^2 - 15.7t + 48.5$$

$(t - 1.6)^2$

$t(t - 1.6) - 1.6(t - 1.6)$

$t^2 - 1.6t - 1.6t + 2.56$

$t^2 - 3.2t + 2.56$

$$-15.7t + 48.5 = 0$$

$$\frac{15.7t}{15.7} = \frac{48.5}{15.7}$$

$$t = 3.09 \text{ s}$$

$$S = d - 36$$

$$d = 4.9(3.09)^2$$

$$d = 47 \text{ m}$$

for the second stone

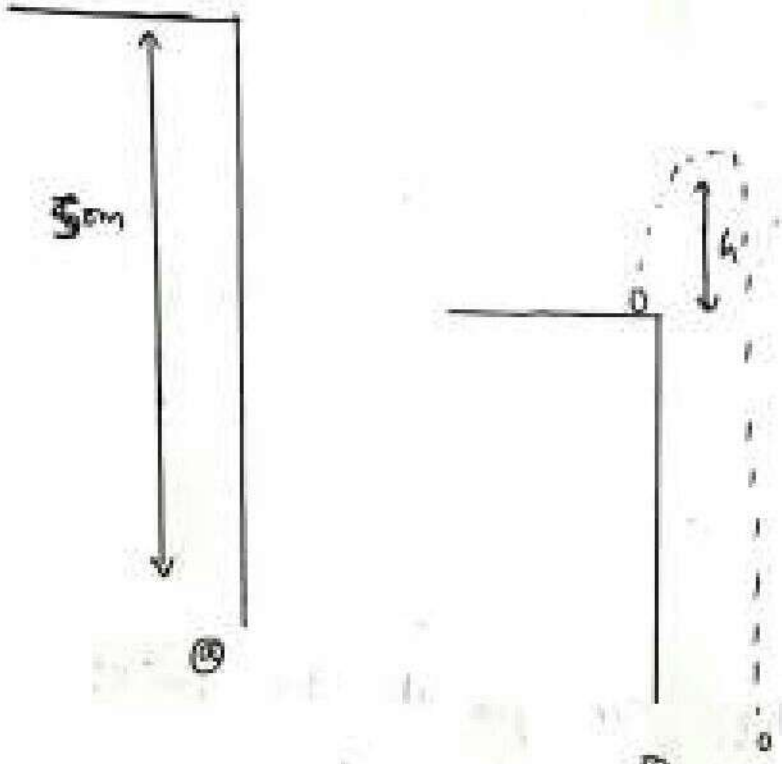
$$d = 47 - 36 = 11 \text{ m}$$

Question 13

DATA

$V_i = 20 m/s$

$H = 50m$



(a) AT maximum height

$V_f = 0 m/s$

$V_i = 20 m/s$

$a = -9.8 m/s^2$

$t = \frac{V_f - u_i}{a}$

$t = \frac{0 - 20}{-9.8}$

$t = 2.05_s$

The Maximum height

(b) $S = v_i t + \frac{1}{2} a t^2$

$S = (20 m/s)(2.05) + \frac{1}{2}(-9.8)(2.05)^2$

$S = 41 + (-4.9)(4.20)$

$S = 41 - 20.6$

$S = 20.4$

(c) time = 2 time taken in the rise

$= 2(2.05)$

$= 4.1_s$

(a) The velocity of the ball

- Ignoring air resistance

$v_f = v_i = 20 m/s$

(e) The velocity and position of the ball at $t = 5_s$

$V_f = 20 m/s + (-9.8)(5)$

$V_f = 20 m/s - 49 m/s$

$V_f = -29 m/s$

$$s = v_i t + \frac{1}{2} g t^2$$

$$s = (20)(5) + \frac{1}{2}(-9.8)(5)^2$$

$$s = 100 + (-4.9)(25)$$

$$s = 100 - 122.5$$

$$s = -22.5 \text{ m}$$

The -ve means the stone will be below the starting point

(13) $v = u + at$

$v = 4 + (-9.8)(3)$

$v = -25 \text{ m/s}$

ola

25 m/s downwards

QUESTION 4

DATA

Stone 1

$V_i = 0 \text{ m/s}$

$a = -9.8 \text{ m/s}^2$

Stone 2

$V_i = 50 \text{ m/s}$

$a = -9.8 \text{ m/s}^2$

$$S = V_i t + \frac{1}{2} a t^2$$

• for stone 1

$$S = 0 + \frac{1}{2}(-9.81)t^2$$

$$S = -4.9t^2 \quad \ldots \quad (1)$$

for stone 2

$$S = 50t + \frac{1}{2}(-9.8)t^2$$

$$S = 50t - 4.9t^2 \quad \ldots \quad (2)$$

Question 14

- Let the two stones meet at a distance x m from the top of the tower

t be the time taken.

let downward direction positive

- for the stone that was dropped

$V = 0 m/s$

$S = x$

$g = 9.8 m/s^2$

$x = v_i t + \frac{1}{2} a t^2$

$x = 0 + \frac{1}{2}(9.8) t^2$

$x = 4.9 t^2$ . . . . . ①

for the stone projected vertically upwards

$v_i = -50 m/s$

$S = -(200 - x)$

$s = v_i t + \frac{1}{2} a t^2$

$-(200 - x) = -50t + \frac{1}{2}(9.8) t^2$

$-(200 - x) = -50t + 4.9t^2$

$(200 - x) = 50t - 4.9t^2$

$200 = 50t - 4.9t^2 + x$

$200 = 50t - 4.9t^2 + (4.9t^2)$

QUESTION 1.5

let

v_i = initial velocity

v_f = final velocity

h = heights attained

a = acceleration

t = time

A stone

B are thrown upwards with velocity u so, $v_f = 0$ at maximum height h also $a = -g$

Now using $v_f = v_i + at$

$$0 = v_i - gt_a$$

$$t_a = \frac{v_i}{g}$$

Where t_a = time of ascent

Also by using $v_f^2 = v_i^2 + 2as$

$$0 = v_i^2 + 2gh$$

$$v_i = \sqrt{2gh} \quad \ldots\ldots\ldots \text{(2)}$$

from equation 1 and (2) we get

$$t_a = \sqrt{\frac{2h}{g}} \quad \ldots\ldots \text{(3)}$$

Descent

Body Comes down from height h so, $u = 0$

and $a = g$

$$v_f = v_i + at$$

$$v_f = 0 + gt_d$$

$$v_f = gt_d \quad \ldots\ldots (1)$$

where t_d = Time for descent

$$t_d = \frac{v_f}{g}$$

Now using $v_f^2 = v_i^2 + 2as$

$$v_f^2 = 0 + 2as$$

$$v_f = \sqrt{2gh}$$

$$v_f = \sqrt{2gh}$$

$$t_d = \frac{\sqrt{2gh}}{g}$$

$$t_d = \frac{\sqrt{2h}}{g}$$

$$t_a = t_d .$$

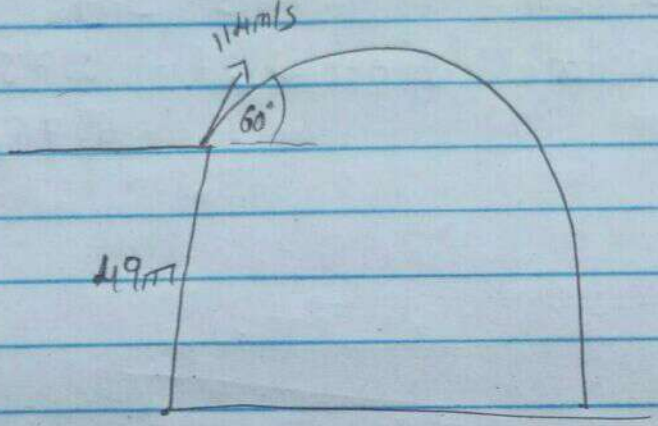
(c) $v = 3 - 2t$

$a = -2$

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

this means that acceleration is not dependent on time

10.



$T = \frac{V_0 \sin\theta}{g}$

$T = \frac{114 \sin 60}{9.8}$

$T = 10.07s$

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

$= \frac{114^2 (\sin 60)^2}{2(9.8)}$

$H = 497.3m$

$\therefore$ max Height $= 497.5 + 49 = 546.5m$

(c) $S = ut + \frac{1}{2}at^2$

$-49 - 49 = 114 \sin 60 \cdot t + \frac{1}{2}(-9.8)t^2$

$-49 = 98.7t - 4.9t^2$

$49 + 98.7t - 4.9t^2$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$x = \frac{-98.7 \pm \sqrt{(98.7)^2 - 4(-4.9)(49)}}{2(-4.9)}$

$t = 20.6s$ as the positive value!!

(d.) $R = V_x \cos\theta \, t$

$= 114 \cos 60 \times 20.6$

$= 1174.2 \text{ m}$

(e.) since the horizontal velocity does not change therefore

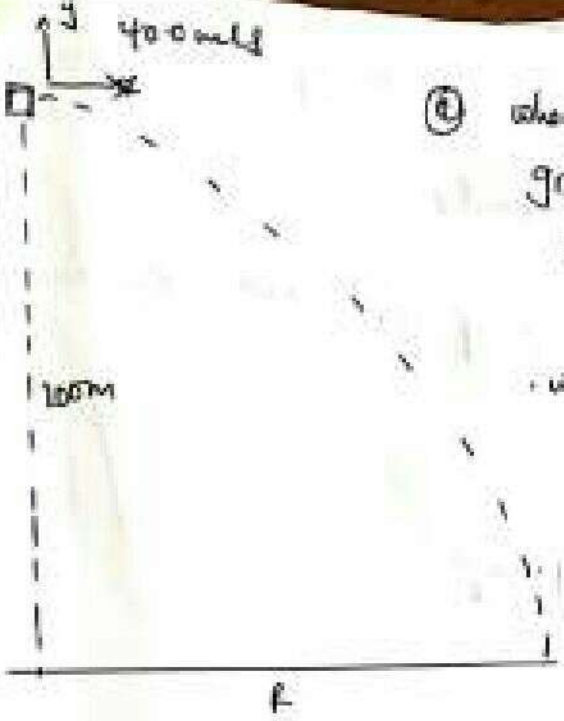
$V_x = V_0 \cos\theta$

$V_x = 114 \cos 60 = 57 \text{ m/s}$

$V_y = V_0 + gt$

$V_y = 114 \sin 60 + (-9.8)(20.6)$

$V_y = -103.2 \text{ m/s}$



④ where does the package strike the ground relative to the point at which it was released?

we want to get the horizontal range

$u = 0$

$s = -100m$

the downward acceleration is

$a = g = 9.81 m/s^2$

So we use $+\frac{1}{2} at^2$

$$-100m = 0 + 0.5(-9.81 m/s^2) t^2$$

$$\frac{100 m}{4.9 m/s^2} = \frac{4.9 m/s^2 t^2}{4.9 m/s^2}$$

$$t = \sqrt{\frac{100}{4.9 s^2}}$$

$$t = 4.52 s$$

$4.52 s$ is the time of flight.

$$x = V_x t$$

$$x = 40 m/s (4.52) s$$

$$x = 180.8 m$$

(b) The horizontal Component of Velocity does not change and is V_x = Hmle

To find V_y we are going to use Kinematics

$V_i = 0$

The time of flight is $t = 4.52_s$

The downward acceleration is

$$a = -g = -9.81 \, m/s^2$$

$$V_{fy} = V_{iy} + gt$$

$$= 0 - 9.81 \, m/s^2 (4.52_s)$$

$$V_{fy} = -44.3 \, m/s$$

(c)

$$\tan\theta = \left(\frac{V_{fy}}{V_{ix}}\right)$$

$$\theta = \tan^{-1}\left(\frac{-44.3}{40}\right)$$

$$\theta = -47.9^\circ$$


Stay here. And don't get
Into any trouble.
It's a Church. What are we
gonna do? Pray to hard?