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

PH 110 INTRODUCTORY PHYSICS

TUTORIALSHEET 3_2022: Kinematics

1. A ball with an initial speed of 5.0 m/s rolls up an incline, sometime later, at a distance of 5.5 m up the incline, it has a speed of 1.5 m/s down the incline.
   (a) Determine:
   (i) its acceleration, (ii) its average velocity and (iii) the time taken to acquire this velocity.
   (b) At some point of the balls journey the velocity had to be zero. Where and when did this occur?

2. A bullet in a rifle accelerates uniformly from rest at 65 000 m/s^2. If the velocity of the bullet as it leaves the muzzle is 450 m/s, (i) how long is the rifle barrel? (ii) How long did it take for the bullet to travel the length of the barrel? (iii) What is the average speed of the bullet?

3. A white car is stopped at a red light. As the light turns green, it accelerates forward at 2.0 m/s^2. At the exact same instant, a red car passes by travelling at 65 km/h. When and how far down the road will the car again meet? Sketch the distance-time graph for each car on the same graph. What was the average velocity of the white car for this time interval? For the red car? Compare the two and explain the results.

4. You brake your car from 75 km/hr to 45 km/hr over a displacement of 88 m.
   (a) What is the acceleration assumed to be constant?
   (b) What is the elapsed time?
   (c) If you continue to slow down with the acceleration calculated in (a), how much time would elapse in bringing the car to rest from 75 km/hr?
   (d) In (c) above, what distance will be covered?

5. A cyclist, starting from rest, accelerates at 0.30 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.

6. A ball thrown vertically upward is caught by the thrower after 2.00 s. Find (a) the initial speed of the ball and (b) the maximum height the ball reaches.

7. 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.

8. 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.

9. A particle is moving along the x axis. Its velocity as a function of time is given by:

$$v = 5 + 10t$$

where v is in m/s. The position of the particle at $t = 0$ is 20 m. Find (a) the acceleration as a function of time, (b) the position as a function of time, and (c) the velocity of the particle at $t = 0$

10. A projectile is fired with an initial speed of 113 m/s at an angle of 60 ^{o} 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. Just as a car starts to accelerate from rest at a constant acceleration of 2.44m/s^2, a bus moving at a constant speed of 19.6m/s passes the car in a parallel lane.
a) How long does it take the car to overtake the bus?
b) How fast is the car moving?
c) How far has the car gone at that point?

13. 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.

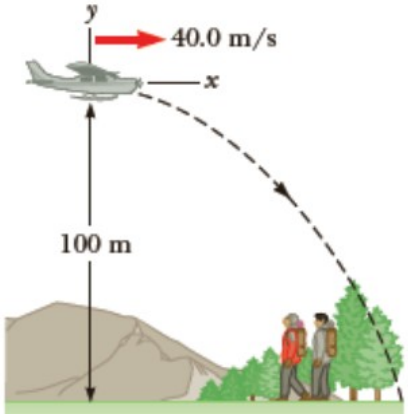
b) Determine the maximum height.
c) The time at which the ball returns to the height from which it was thrown.
d) The velocity of the ball at this instant.
e) The velocity and position of the ball at t = 5s.

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?

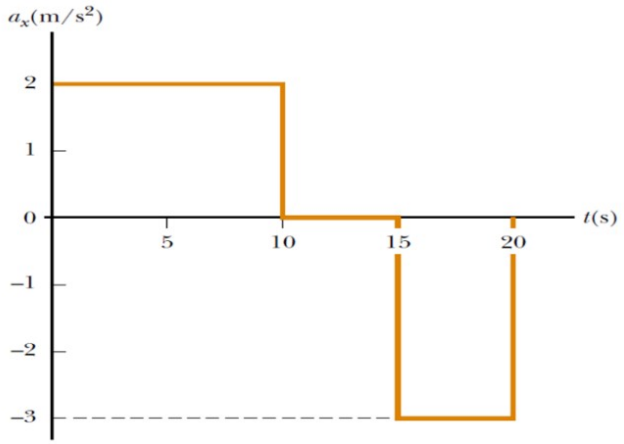
17. An Alaskan rescue plane drops a package of emergency rations to stranded hikers, as shown in the Figure below. The plane is traveling horizontally at 40.0 m/s at a height of 1.0x 10^2 m above the ground. Neglect air resistance.



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?

18. 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.



19. 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.

QUESTION 10

DATA

x motion

$x = ?$

$V_{0x} = 113 \cos 60^\circ$

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

y - motion

$y_B = -49m$

$V_{0y} = 113 \sin 60^\circ$

$V_{Ay} = 0$

$a_y = -9.8 m/s^2$

(a)

$V_{fy} = V_{iy} + gt_1$

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

$= \dfrac{0 - 113 \sin 60^\circ}{-9.8}$

$= 9.99_s$

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

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

$y = 489m$

© finding the total time in the air

$$Y = V_{0y} + \frac{1}{2} a_y t_2^2$$

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

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

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

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

We reject the second solution (it gives the time the projectile would leave 49ft the ground, if it had been thrown from there)

(a) Find the horizontal range (x_B)

$$V_{Bf} = V_i t + \frac{1}{2} g t^2$$

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

(b) find the components of the final velocity

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

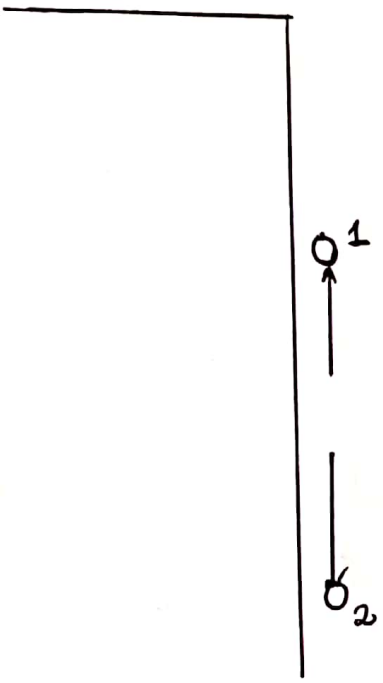
$$= 113 \sin 60 - 9.8(20.5)$$

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

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

DATA

Stone 1	Stone 2
$u = 0 m/s$	$u = 6 m/s$
$t = t$	$t = t - 1.6$
	$d = d - 36$
$a = 9.8 m/s^2$	$a = 9.8 m/s$



for Stone 1

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

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

$$d = 4.9 t^2 \quad \ldots \ldots \text{(1)}$$

Stone 2

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

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

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

$$(t - 1.6)^2$$

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

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

$$t^2 - 3.2t + 2.56$$

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

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

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

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

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

$-15.7t + 48.5 = 0$

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

$t = 3.09\ s$

$s = d - 36$

$d = 4.9(3.09)^2$

$d = 47m$

for the second stone

$d = 47 - 36 = 11m$

QUESTION 12

Car

$a = 2.44 m/s^2$

$v_i = 0 m/s$

Bus

$V = 19.6 m/s$

$a = 0 m/s$

(a) How long does it take to overtake the bus

• Car

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

$s = 0 + \frac{1}{2}(2.44)t^2$

$s = 1.22 t^2$ ..... (i)

The bus

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

$s = 19.6t + 0 = 19.6t$

$s = 19.6t$ ... (ii)

$V_f = v_i$

$$\frac{19.6t}{1.22t} = \frac{1.22t^2}{1.22t}$$

$$t = 16.1\,s$$

(b) How fast is the car moving?

$t = 16.1\,s$

$v_i = 0\ m/s$

$a = 2.44\ m/s^2$

$v_f = v_i + at$

$v_f = 0 + (2.44)(16.1)$

$v_f = \underline{39.3\ m/s}$

(c) How far has the car gone at the point?

$s = 1.22t^2$

$s = 1.22(16.1)^2$

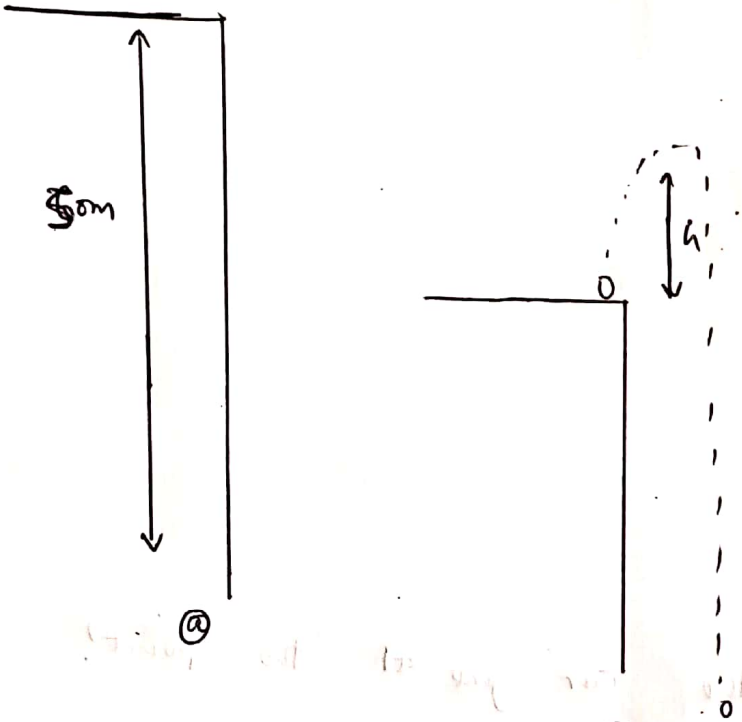
$s = 316.2\ m$

QUESTION 13

DATA

$V_i = 20 m/s$

$H = 50m$



@ AT maximum height

$V_f = 0 m/s$

$V_i = 20 m/s$

$a = -9.8 m/s^2$

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

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

$t = 2.05_5 s$

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

$= 2(2.05)$

$= 4.1 s$

(d) The velocity of the ball

- Ignoring air resistance

$v_f = v_i = 20 m/s$

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

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

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

$V_f = -29 m/s$

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

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

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

$s = 100 - 122.5$

$s = -22.5\ m$

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

QUESTION 4

DATA

Stone 1	Stone 2
$v_i = 0\ m/s$	$v_i = 50 m/s$
$a = -9.8\ m/s^2$	$a = -9.8 m/s^2$

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

• for stone 1

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

$s = -4.9t^2$ ..... ①

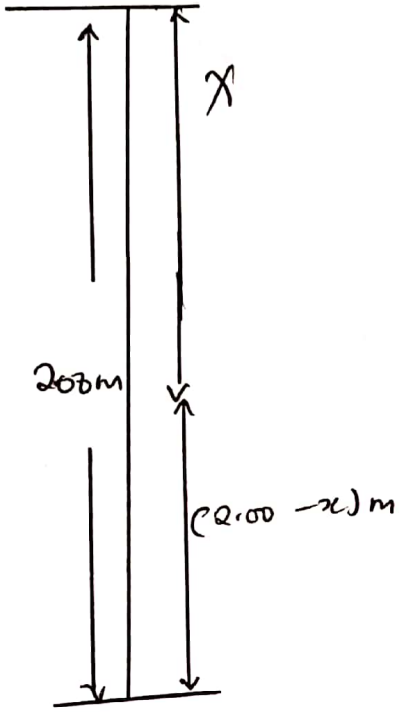
for stone 2

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

$s = 50t - 4.9t^2$ ..... ②

$-4.9t^2 = 50t - 4.9t^2$

QUESTION 14



Let us assume the downward direction positive

Stone 1 Stone 2

$v_2 = 50 m/s$

$v_1 = 0 m/s$

$a = 9.8 m/s^2$

$a = 9.8 m/s^2$

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

For Stone 1

$s =$

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 droped

$V = 0 m/s$

$s = x$

$g = 9.8 m/s^2$

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

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

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

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 15

Let

v_i = initial velocity

v_f = final velocity

h = heights attained

a = acceleration

t = time

Ascent

A ball 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

Ball is Thrown down from height h so, $u = 0$

and $a = g$

$$v_f = u_i + at$$

$$v_f = 0 + gt_d$$

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

where t_d = Time of descent

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

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

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

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

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

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

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

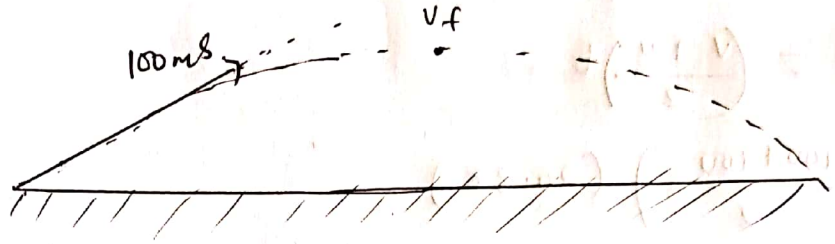
$$t_a = t_d .$$

Question 16

$v_i = 100 \text{ m/s}$

(a) too

$g = -9.8$



total

(i) find the time of flight

$v_t = v_i + at$

$0 = 100 \text{ m/s} + (-9.8)\, t$

$\frac{100 \text{ m/s}}{9.8 \text{ m/s}^2} = \frac{9.8 \text{ m/s}^2 t}{9.8 \text{ m/s}^2}$

$t = 10.2 \text{ s}$

So total time

$2t = 2(10.2)$

$= 20.4 \text{ s}$

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

$s = (100)(10.2) + \frac{1}{2}(-9.8)(10.2)^2$

$s = 1020 - 509.8$

$s = 970.00 \text{ m}$

$s = (100)(20.4 \text{ s}) - 4.9 (20.4)^2$

$s = - 2039.2$

$s =$

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

$s = (100)(20.4) + \frac{1}{2}(9.8)(20.4)^2$

$s = 2040m - 2039.2\ m$

$s = \left(\frac{v+u}{2}\right)t$

$s = \left(\frac{100+100}{2}\right)(20.38)$

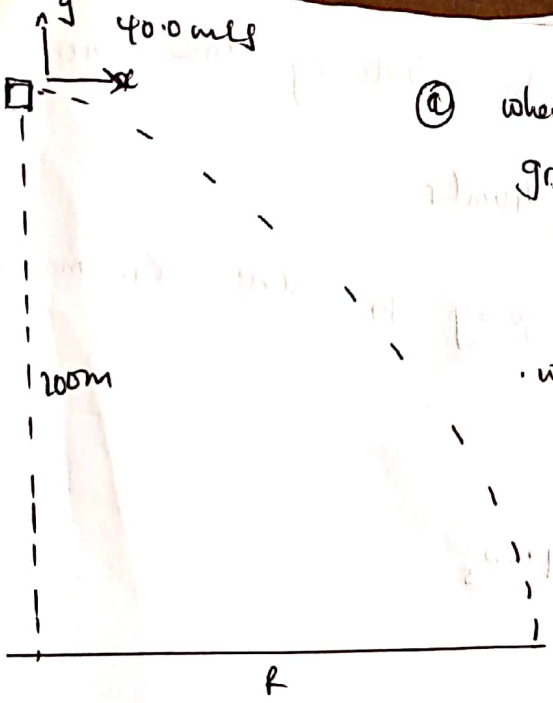
$s = 2038cm$

(iii) $u = v = 100m/s$

(iv) The assumption is that the air does not affect the motion and the bullet falls freely under the influence of only gravity

$v.\ 0 = 40m/s + (-9.8)t$

$40 = 9.8t$



(a) 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

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

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

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

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

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

$t = 4.52 s$

$4.52 s$ 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 $V_x = 40 m/s$

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)

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

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

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

QUESTION 18

(a) $v_f = v_i + at$

$v_i = 0 \qquad a = 2 m/s^2$

$v_f = 2 m/s^2 \times 10 s$

$v_f = 20 m/s$

(b) $v_f = v_i + at$

~~$v_f = 0 + 20 \times$~~

The speed of the particle at $t = 15.0 s$ is

$v_i = 20 m/s \qquad a = -3 m/s$

~~$v_f = 20 m/s + 3 \times 15$~~

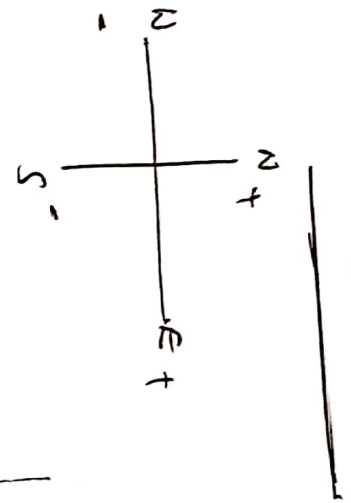
~~$2 = 3$~~

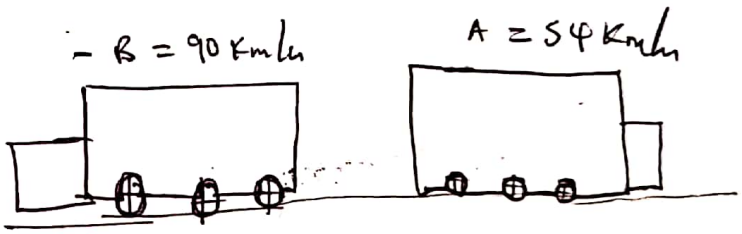
$v_f = 20 m/s - 3 m/s^2 \times 5 s$

$v_f = 20 m/s - 15 m/s$

$v_f = 5 m/s$

Question 6





(a) $\vec{V}_{BA} = \vec{V}_B - \vec{V}_A$

$V_{BA} = 54 - (-90)$

$V_{BA} = 144 \text{ Km/h}$

(b) Velocity of ground w.r.t B

$\vec{V}_{gB} = \vec{V}_g - \vec{V}_B$

$\vec{V}_{gB} = -90 \text{ Km/hr}$ (towards North)

(c) $\vec{V}_{mg} = \vec{V}_{mA} + \vec{V}_{Ag}$

$\vec{V}_{mg} = 18 \text{ Km/h} - 54$

$\vec{V}_{mg} = -36 \text{ Km/h}$