Name: _____

Class: _____

Due Date: _____

A.1 Kinematics

Understandings

- The motion of bodies through space and time can be described and analyzed in terms of position, velocity, and acceleration.
- The velocity is the rate of change of position and acceleration is the rate of change of velocity.
- The change in position is the displacement.
- The difference between distance and displacement.
- The difference between the instantaneous and average values of velocity, speed, and acceleration, and how to describe them.
- The equations of motion for solving problems with uniformly accelerated motion as given by
  - $s = \frac{u+v}{2}t$
  - $v = u + at$
  - $s = ut + \frac{1}{2}at^2$
  - $v^2 = u^2 + 2as$
- Motion with uniform and non-uniform acceleration.
- The behavior of projectiles in the absence of fluid resistance, and the application of the equations of motion resolved into vertical and horizontal components.
- The qualitative effect of fluid resistance on projectiles, including time of flight, trajectory, velocity, acceleration, range, and terminal speed.

Equations

$s = \frac{u+v}{2}t$

$v = u + at$

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

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

Interesting facts

- The record for the tallest person in the world is Robert Wadlow who measured 272 cm. He died at the age of 22.
- The record for the tallest building in the world is the Burj Khalifa in the United Arab Emirates which is almost 830 m tall.
- The record for the tallest mountain above sea level is Mount Everest which is located between China and Nepal. It is measured to be about 8,848 m above sea level.
- The record for the lowest depth below sea level is the Mariana Trench which is about 10,984 m below sea level. Surprisingly both life and pollution is found near the bottom of the Marina Trench.
- The fastest baseball pitch ever recorded is from Aroldis Chapman at which was about 169.1 km/h or 46.97 m/s.

Super Ultimate Graphing Challenge
http://theuniverseandmore.com/

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Use your favorite sources to answer the following questions

1. What is the meaning of zero dimensions? One dimension? Two dimensions? Three dimensions? Four dimensions? If possible draw a figure for each.

2. Define *position.*

3. Define *distance*. Scalar or vector? Units? Example? Can *distance* be negative?

4. Define *displacement*. Scalar or vector? Units? Example? Can *displacement* be negative?

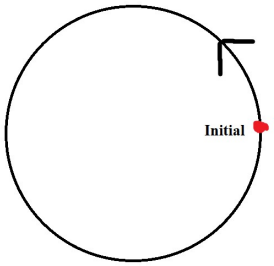
5. Define *speed*. Scalar or vector? Equation? Units? Example? Can *speed* be negative?

6. Define *velocity*. Equation? Units? Example? Can *velocity* be negative?

7. Define *average speed*. Scalar or vector? Equation? Units?

8. Define *average velocity*. Scalar or vector? Equation? Units?

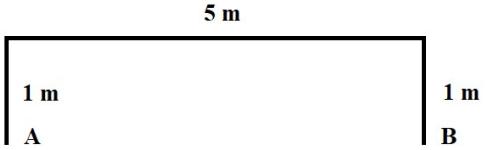
9. An object moves in a circle with a radius of 3 m. It takes the object 4 seconds to complete one revolution.



   a. What is the average speed and the average velocity of the object after it completes **one** cycle/revolution?

   b. What is the average speed and the average velocity of the object after it completes **one-half** cycle/revolution?

10. An object starts from rest at point A and then travels to point B by moving north 1 m, then east 5 m, and finally south 1 m in a total time of 14 seconds. What is the average speed and the average velocity of the object when it moves from point A to point B?



11. Define *instantaneous speed*. Example?

12. Define *instantaneous velocity*. Example?

13. Define *acceleration*. Equation? Units? Example? Can *acceleration* be negative?

14. What is the magnitude of the acceleration of free fall $\vec{g}$ near the surface of the Earth? Which direction/way does it point? Is it positive or negative?

15. Define *projectile motion.*

16. What does the slope of a *displacement vs. time* graph tell us? Equation? Units?

17. What does the slope of a *velocity vs. time* graph tell us? Equation? Units?

18. What does the slope of an *acceleration vs. time* graph tell us? Equation? Units?

19. What does the area under a *displacement vs. time* graph tell us? Units?

20. What does the area under a *velocity vs. time* graph tell us? Units?

21. What does the area under an *acceleration vs. time* graph tell us? Units?

22. How would you go about determining the acceleration due to gravity near the surface of the Earth? Which equation will you use? Which instruments do you need? What will you do?

23. **Use a pencil and ruler!** Define *terminal velocity*. What is the relationship between speed and the force of friction? Draw a *distance vs. time* graph, a *speed vs. time* graph, and an *acceleration vs. time* graph of an object being dropped from rest from a very high height above the surface of the Earth with both the force of friction and the force of gravity acting on it.

24. **Use a pencil and ruler!** Draw a *speed vs. time* graph of a skydiver first jumping out of an airplane, then reaching terminal velocity, then opening his parachute, then reaching a second terminal velocity, and finally hitting the ground.

25. A ball/projectile is thrown with an initial angle of 50 degrees. Draw its trajectory with no air friction and with air friction.

26. A ball is thrown vertically upwards with an initial velocity of 40 m/s in the absence of air friction. For this problem let the acceleration due to gravity be 10 m/s^2 down.

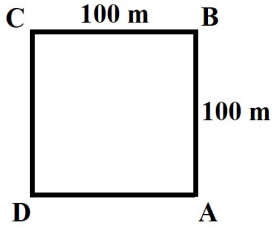
a. Fill out the table below:

Time (s)	Acceleration $\left[\frac{\text{m}}{\text{s}^2}\right]$	Velocity $\left[\frac{\text{m}}{\text{s}}\right]$ $v_\text{f} = at + v_\text{i}$	Displacement [m] $y_\text{f} = \frac{1}{2}at^2 + v_\text{i}t + y_\text{i}$	Total distance traveled [m]
0				
1				
2				
3				
4				
5				
6				
7				
8				

b. **Use a pencil and ruler!** Draw an *acceleration vs. time* graph, a *velocity vs. time* graph, a *speed vs. time* graph, a *displacement vs. time* graph, and a *distance vs. time* graph for the ball.

Part 2: Distance Displacement Speed Velocity

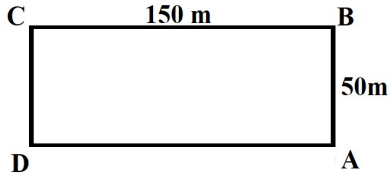
1. Wayde Van Niekerk from Russia runs 400 meters at a constant speed around a square track in a time of 43.03 seconds beginning at point A in a counterclockwise direction as shown below.



Complete the following table by determining the distance, displacement, speed, and velocity of Wayde Van Kiekerk at the following points. State both the magnitude and direction for the displacement and velocity of Wayde Van Kiekerk.

	Point B	Point C	Point D	Point A
Total Distance				
Total Displacement				
Average Speed				
Average Velocity				

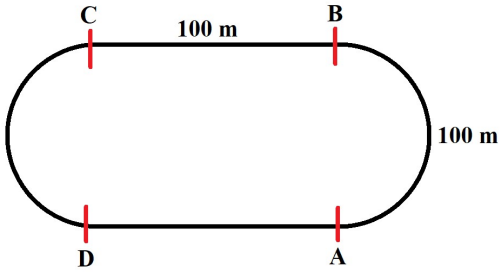
2. Wayde Van Niekerk from Russia runs 400 meters at a constant speed around a rectangular track in a time of 43.03 seconds beginning at point A in a counterclockwise direction as shown below.



Complete the following table by determining the distance, displacement, speed, and velocity of Wayde Van Kiekerk at the following points. State both the magnitude and direction for the displacement and velocity of Wayde Van Kiekerk.

	Point B	Point C	Point D	Point A
Total Distance				
Total Displacement				
Average Speed				
Average Velocity				

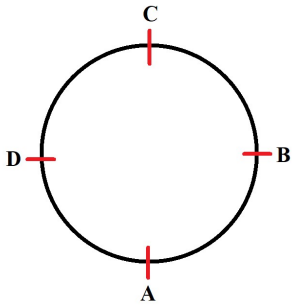
3. Wayde Van Niekerk from Russia runs 400 meters at a constant speed around an Olympic track in a time of 43.03 seconds beginning at point A in a counterclockwise direction as shown below. Each semicircle has a length of 100 meters.



Complete the following table by determining the distance, displacement, speed, and velocity of Wayde Van Kiekerk at the following points. State both the magnitude and direction for the displacement and velocity of Wayde Van Kiekerk.

	Point B	Point C	Point D	Point A
Total Distance				
Total Displacement				
Average Speed				
Average Velocity				

4. Wayde Van Niekerk from Russia runs 400 meters at a constant speed around a circular track in a time of 43.03 seconds beginning at point A in a counterclockwise direction as shown below.

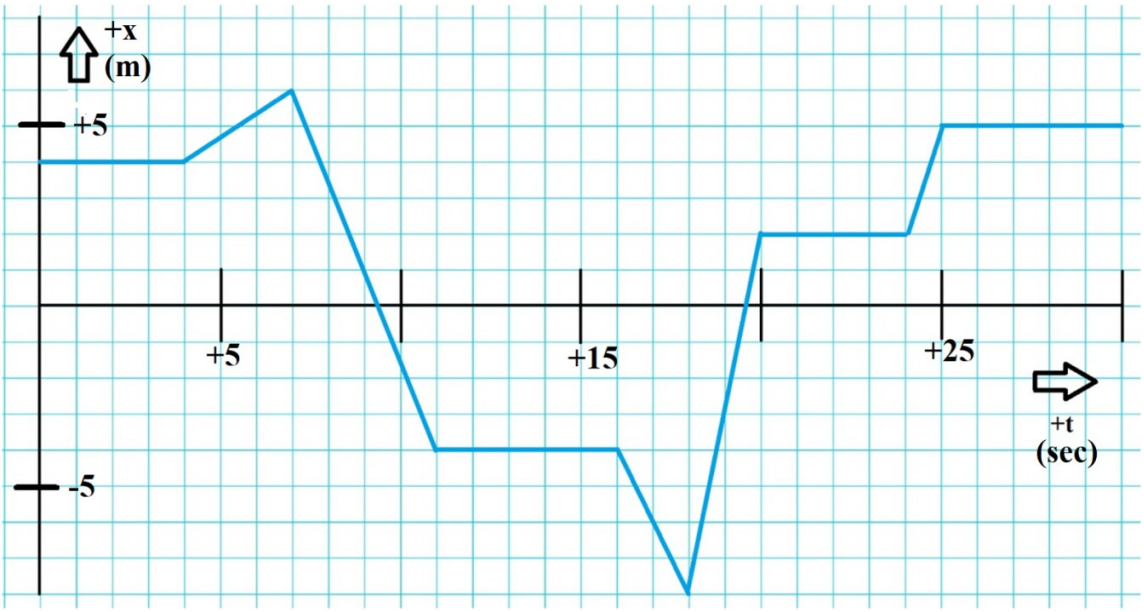


Complete the following table by determining the distance, displacement, speed, and velocity of Wayde Van Kiekerk at the following points. State both the magnitude and direction for the displacement and velocity of Wayde Van Kiekerk.

	Point B	Point C	Point D	Point A
Total Distance				
Total Displacement				
Average Speed				
Average Velocity				

Part 3: Motion graphs

1. An object can move to the left or right in one dimension. Positive displacement is towards the right and negative displacement is towards the left. Its *displacement vs. time* graph is shown below.



a. What does the slope of a *displacement vs. time* graph tell us?

b. Determine the *displacement* and *velocity* of the object at

i. $t = 3$ s

ii. $t = 5$ s

iii. $t = 9$ s

iv. $t = 13$ s

v. $t = 17$ s

vi. $t = 19$ s

vii. $t = 23$ s

viii. $t = 24.5$ s

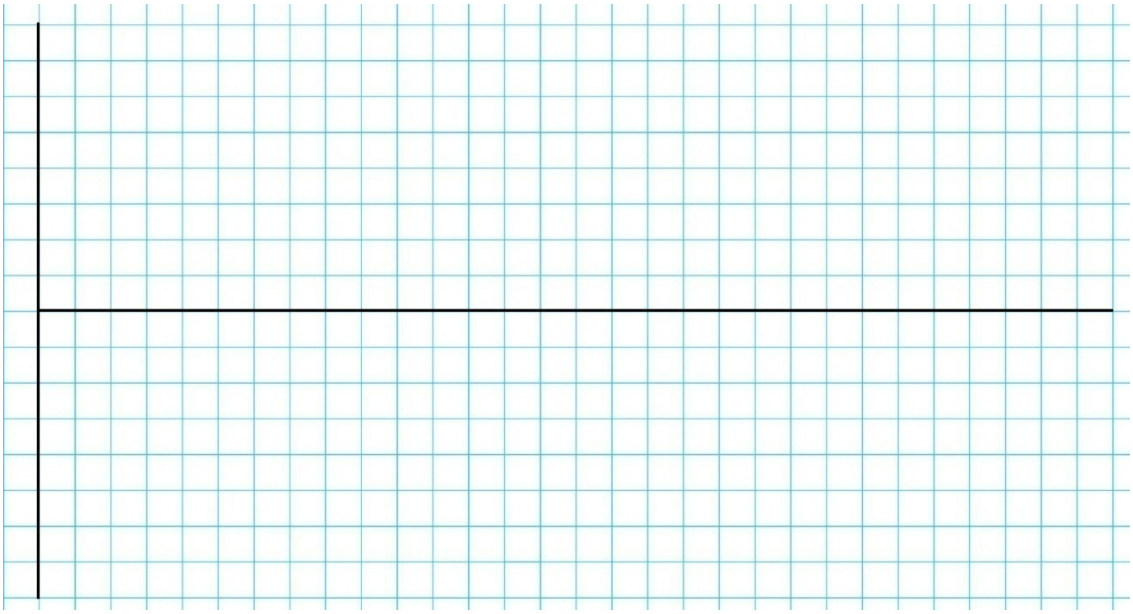
ix. $t = 28$ s

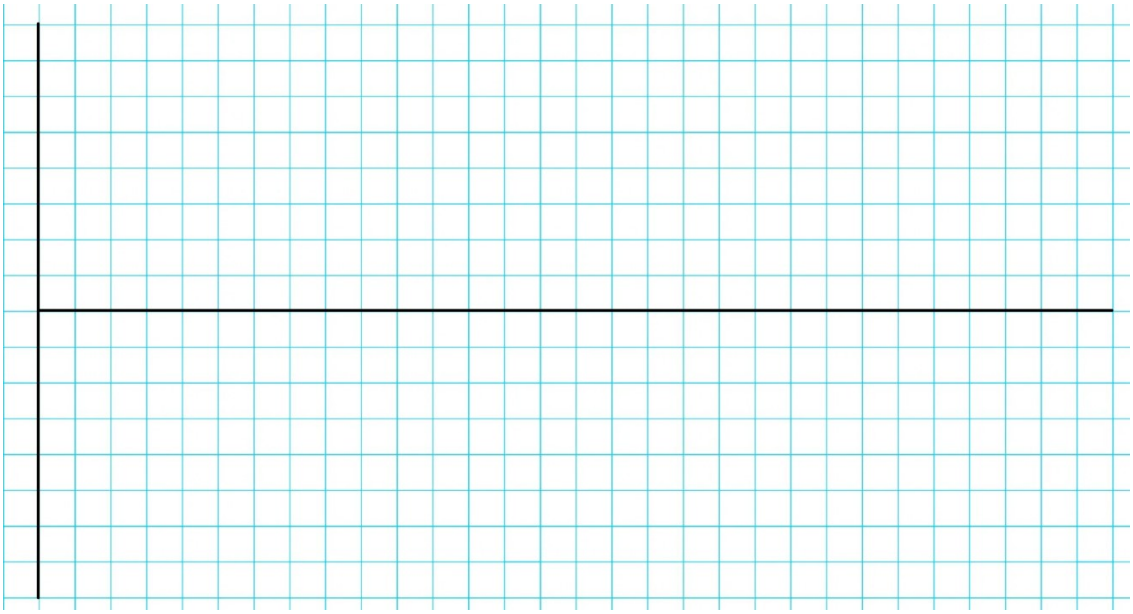
c. What is the *total distance* the object travels from $t = 0$ s to $t = 30$ s?

d. What is the *displacement* of the object from $t = 0$ s to $t = 30$ s?

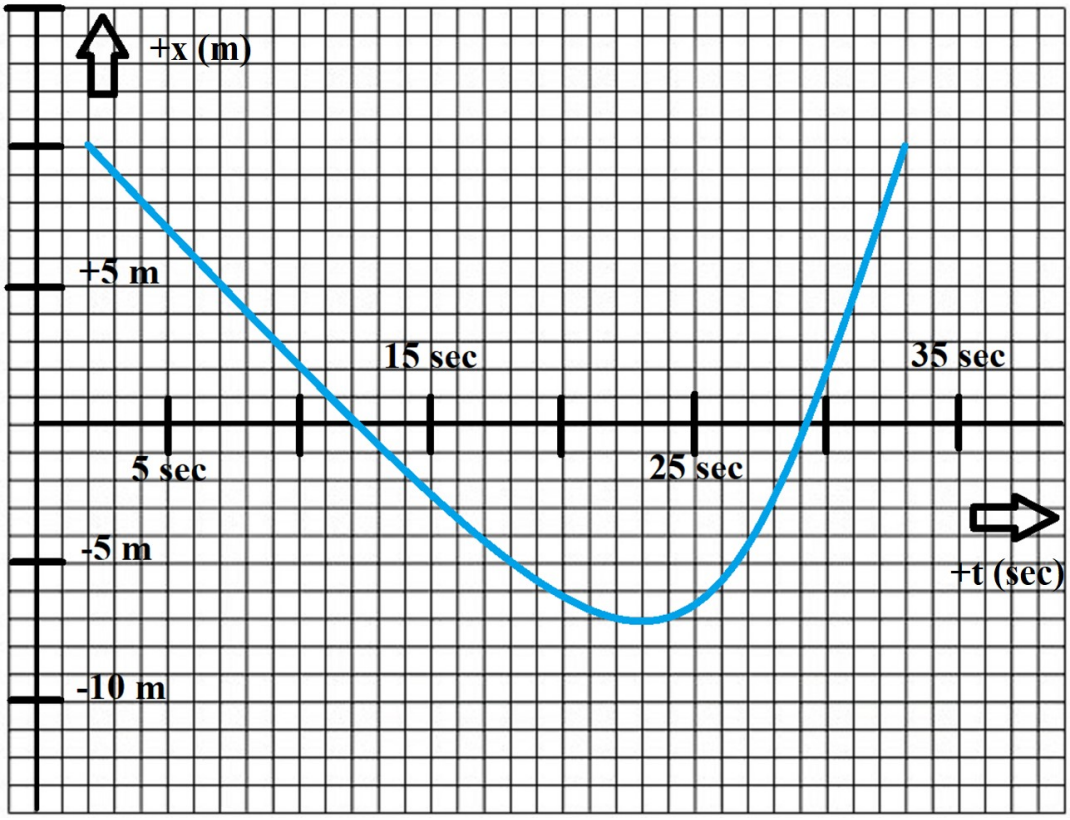
e. What does the slope of a *velocity vs. time* graph tell us?

f. **Use a pencil and ruler!** On the graphs below draw a *velocity vs. time* graph and an *acceleration vs. time* graph. Label your axes!





2. An object can move to the left or right in one dimension. Positive displacement is towards the right and negative displacement is towards the left. Its *displacement vs. time* graph is shown below.



a. Is the object moving to the left or the right? Is it speeding up or slowing down?

i. From $t = 2$ s to $t = 12$ s

ii. From $t = 12$ s to $t = 23$ s

iii. From $t = 23$ s to $t = 29$ s

iv. From $t = 29$ s to $t = 33$ s

b. Determine the *displacement* and *velocity* of the object at

i. $t = 12$ s

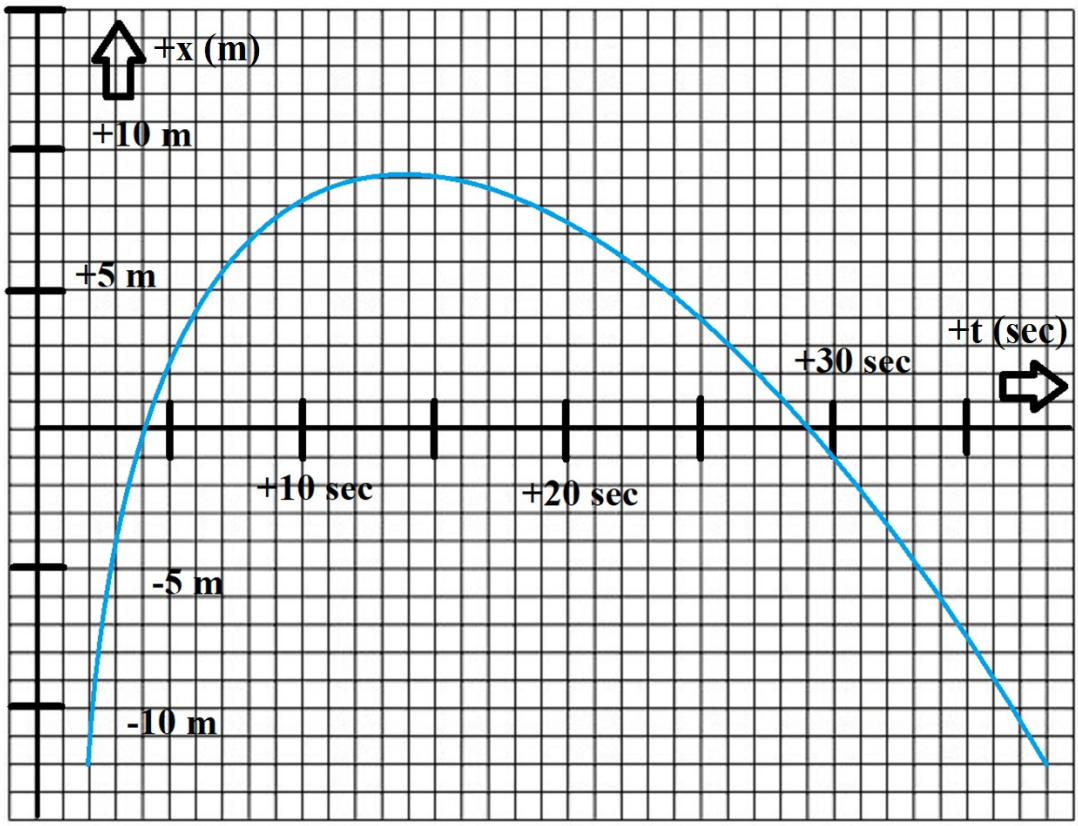
ii. $t = 23$ s

iii. $t = 29$ s

c. What is the *total distance* the object travels from $t = 2$ s to $t = 33$ s?

d. What is the *displacement* of the object from $t = 2$ s to $t = 33$ s?

3. An object can move to the left or right in one dimension. Positive displacement is towards the right and negative displacement is towards the left. Its *displacement vs. time* graph is shown below.



a. Is the object moving to the left or the right? Is it speeding up or slowing down?

i. From $t = 2$ s to $t = 4$ s

ii. From $t = 4$ s to $t = 14$ s

iii. From $t = 14$ s to $t = 29$ s

iv. From $t = 29$ s to $t = 38$ s

b. Determine the *displacement* and *velocity* of the object at

i. $t = 4$ s

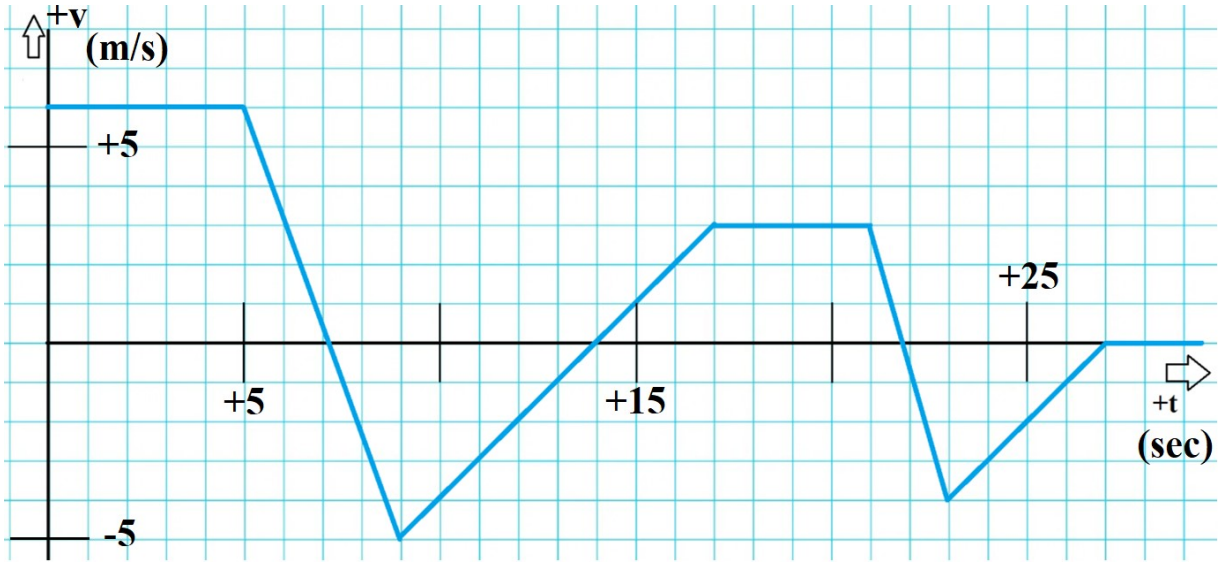
ii. $t = 14$ s

iii. $t = 29$ s

c. What is the *total distance* the object travels from $t = 2$ s to $t = 38$ s?

d. What is the *displacement* of the object from $t = 2$ s to $t = 38$ s?

4. An object can move to the left or right in one dimension. Positive displacement is towards the right and negative displacement is towards the left. Its *velocity vs. time* graph is shown below.



a. What does the slope of a *velocity vs. time* graph tell us?

b. Find the *velocity* and the *acceleration* of the object at

i. $t = 3$ s

ii. $t = 7$ s

iii. $t = 8$ s

iv. $t = 10$ s

v. $t = 14$ s

vi. $t = 18$ s

vii. $t = 22$ s

viii. $t = 29$ s

c. What does the area under a *velocity vs. time* graph tell us?

d. Find the *displacement* of the object from

i. $t = 0$ s to $t = 5$ s

ii. $t = 5$ s to $t = 9$ s

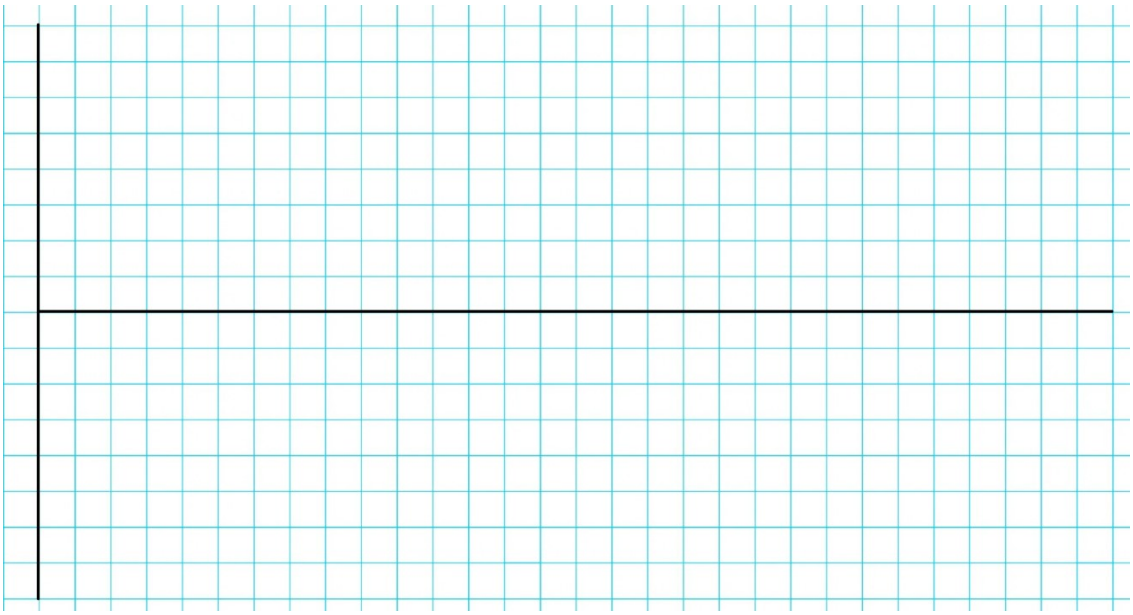
iii. $t = 9$ s to $t = 17$ s

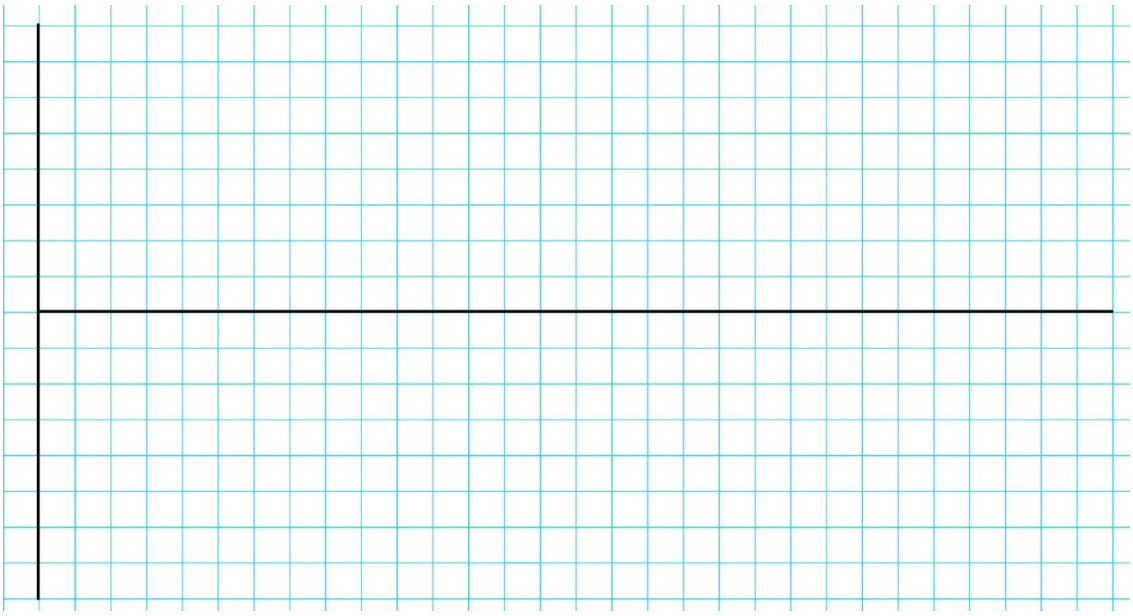
iv. $t = 17$ s to $t = 27$ s

e. Determine the *total distance* the object travels from $t = 0$ s to $t = 29$ s.

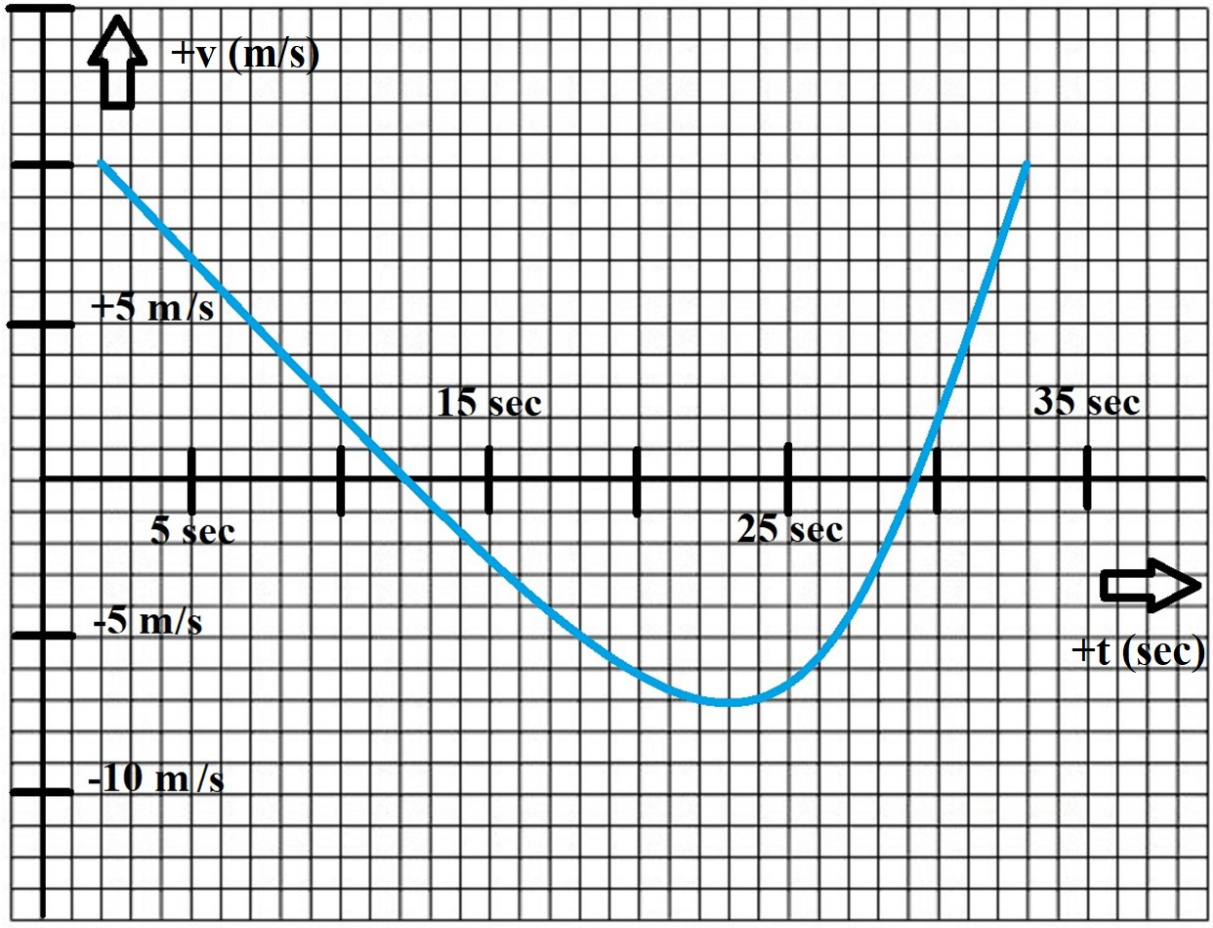
f. Determine the *displacement* of the object from $t = 0$ s to $t = 29$ s.

g. **Use a pencil and ruler!** On the graphs below draw an *acceleration vs. time* graph and a *displacement vs. time* graph. Label your axes!





5. An object can move to the left or right in one dimension. Positive displacement is towards the right and negative displacement is towards the left. Its *velocity vs. time* graph is shown below.



a. Is the object moving to the left or the right? Is its acceleration increasing, decreasing, or constant?

i. From $t = 2$ s to $t = 12$ s

ii. From $t = 12$ s to $t = 23$ s

iii. From $t = 23$ s to $t = 29$ s

iv. From $t = 29$ s to $t = 33$ s

b. Determine the *velocity* and *acceleration* of the object at

i. $t = 12$ s

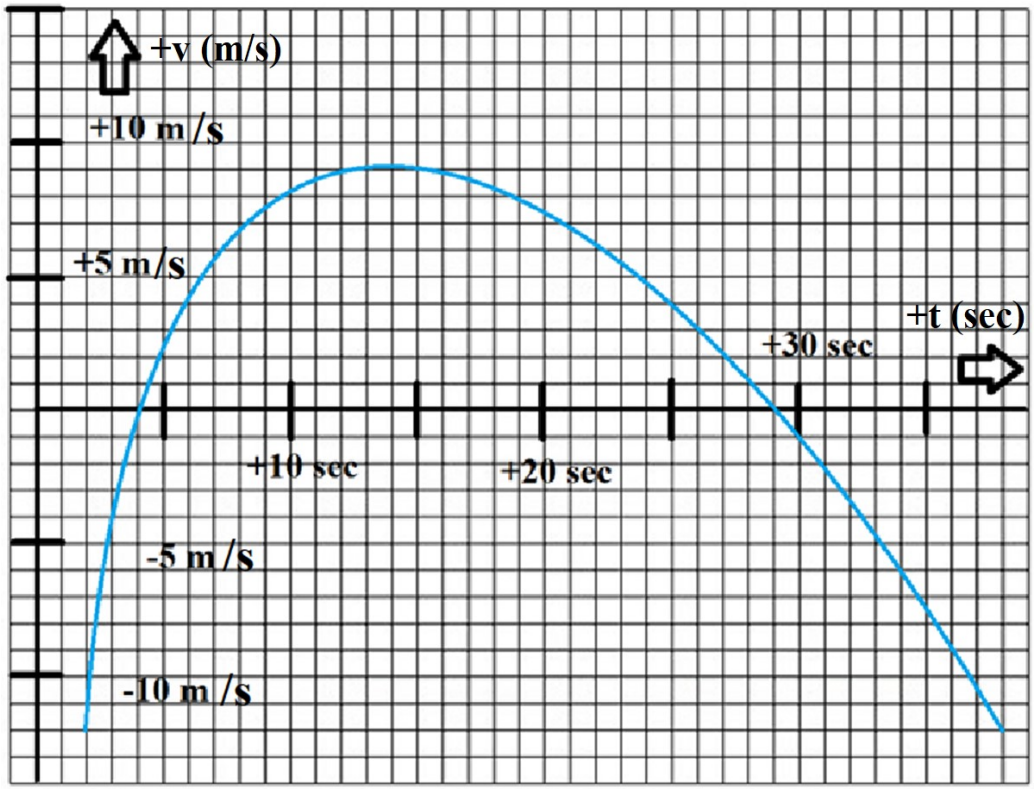
ii. $t = 23$ s

iii. $t = 29$ s

c. Determine the *total distance* the object travels from $t = 2$ s to $t = 33$ s.

d. Determine the *displacement* of the object from $t = 2$ s to $t = 33$ s.

6. An object can move to the left or right in one dimension. Positive displacement is towards the right and negative displacement is towards the left. Its *velocity vs. time* graph is shown below.



a. Is the object moving to the left or the right? Is its acceleration increasing, decreasing, or constant?
   i. From $t = 2$ s to $t = 4$ s
   ii. From $t = 4$ s to $t = 14$ s
   iii. From $t = 14$ s to $t = 29$ s
   iv. From $t = 29$ s to $t = 38$ s

b. Determine the *velocity* and *acceleration* of the object at
   i. $t = 4$ s
   ii. $t = 14$ s
   iii. $t = 29$ s

c. Determine the *total distance* the object travels from $t = 2$ s to $t = 38$ s.

d. Determine the *displacement* of the object from $t = 2$ s to $t = 38$ s.

Part 4: Motion equations

There is no air friction for all the problems. The magnitude of the acceleration from gravity is 9.81 m/s^2. Round your answers to two decimal points.

1. A car starts from rest and speeds up to 35 m/s in 12 seconds.
   a. What is the average acceleration of the car during these 12 seconds?

   b. What is the total distance traveled by the car during these 12 seconds?

   The car then travels at a constant speed of 35 m/s for 900 meters.
   c. How long was the car travelling at this constant speed?

   The car finally slows down from 35 m/s to 15 m/s in four seconds.
   d. What is the average acceleration (or deceleration) of the car during these four seconds?

   e. What is the total distance the car travels during these four seconds?

f. What is the total distance the car travels since it started from rest?

g. What is the total time taken for the car to travel since it started from rest until it reaches a speed of 15 m/s?

h. Draw a *displacement vs. time* graph, a *velocity vs. time* graph, and an *acceleration vs. time* graph for the car.

2. A car starts from rest and accelerates at a constant rate of 4 m/s^2 for 8 seconds.
   a. What is the speed of the car after 8 seconds?

   b. How much distance did the car travel during these 8 seconds?

   The car then moves at a constant speed for 12 seconds.
   c. How much distance did the car travel during these 12 seconds?

   The car then slows to a stop at a rate of 3 m/s^2.
   d. How much time did it take for the car to decelerate and stop?

   e. How much distance did the car travel when it decelerates?

   f. What is the total time taken for the car to travel?

   g. What is the total distance taken for the car to travel?

h. Draw a *displacement vs. time* graph, a *velocity vs. time* graph, and an *acceleration vs. time* graph for the car.

3. Enoch throws a ball vertically upwards with an initial speed of 47 m/s at an elevation of 8,848 m above the surface of the Earth.
   a. What will be the acceleration of the ball (number and direction) at the moment after it is thrown upwards?

   b. What will be the acceleration of the ball (number and direction) when it reaches its maximum height?

   c. What will be the velocity of the ball when it reaches its maximum height?

   d. How long will it take for the ball to reach its maximum height?

   e. How many meters above the surface of the Earth will the ball be when it reaches its maximum height?

   f. What will be the acceleration of the ball (number and direction) just before it strikes the surface of the Earth?

   g. What will be the velocity of the ball when it is 8,950 m above the surface of the Earth?

   h. How long will it take for the ball to be 8,950 m above the surface of the Earth?

i. What will be the velocity of the ball just before it strikes the ground?

j. What is the total distance the ball travels during the first 4.5 s?

k. What is the total distance the ball travels?

l. How long will it take for the ball to be 300 m above the surface of the Earth?

m. Draw a displacement vs. time graph, a velocity vs. time graph, and an acceleration vs. time graph for the ball.

4. Noah drops a ball from rest at an elevation 830 m above the surface of the Earth.

   a. What will be the acceleration of the ball (number and direction) at the moment it is dropped?

   b. What will be the acceleration of the ball (number and direction) when it is 415 m above the surface of the Earth?

   c. What will be the acceleration of the ball (number and direction) just before it strikes the surface of the Earth?

   d. How long will it take for the ball to be 415 m above the surface of the Earth?

   e. What will be the velocity of the ball 415 m above the surface of the Earth?

   f. What will be the velocity of the ball just before it strikes the ground?

   g. What is the total distance the ball travels during the first 8 s?

h. How long will it take for the ball to be 300 m above the surface of the Earth?

i. What is the average speed of the ball?

j. Draw a displacement vs. time graph, a velocity vs. time graph, and an acceleration vs. time graph for the ball.

5. Eber throws a ball vertically downwards with an initial speed of 22 m/s from a height of 8,848 m above the surface of the Earth.

   a. What will be the acceleration of the ball (number and direction) at the moment after it is thrown downwards?

   b. What will be the acceleration of the ball (number and direction) just before it strikes the surface of the Earth?

   c. What will be the velocity of the ball just before it strikes the surface of the Earth?

   d. How long will it take for the ball to reach the surface of the Earth?

   e. What will be the velocity of the ball when it is 4,000 m above the surface of the Earth?

   f. How long will it take for the ball to reach 4,000 m above the surface of the Earth?

   g. What is the total distance the ball travels after 12.5 s?

h. Draw a displacement vs. time graph, a velocity vs. time graph, and an acceleration vs. time graph for the ball.

6. Salah throws a ball with an initial speed of 47 m/s at an angle of 30° north of east 830 meters above the surface of the Earth.

   a. Complete the table:

$x_{\mathrm{i}} =$	$y_{\mathrm{i}} =$
$v_{\mathrm{i,x}} =$	$v_{\mathrm{i,y}} =$
$a_{\mathrm{x}} =$	$a_y =$

   b. What will be the horizontal velocity and horizontal acceleration of the ball (number and direction) when it reaches its maximum height?

   c. What will be the vertical velocity and vertical acceleration of the ball (number and direction) when it reaches its maximum height?

   d. How long will the ball be in the air for?

   e. What will be the range (horizontal distance) of the ball?

   f. What will be the maximum height of the ball from the surface of the Earth after it is thrown?

   g. How long will it take for the ball to reach its maximum height after it is thrown?

h. How long does it take for the ball to reach 400 m above the surface of the Earth after it is thrown?

i. How high above the surface of the Earth will the ball be eight seconds after it is thrown?

j. How far horizontally does the ball travel during the first eight seconds after it is thrown?

k. What will be the velocity of the ball (number and direction) eight seconds after it is thrown?

l. What will be the displacement of the ball (number and direction) eight seconds after it is thrown?

m. Draw an acceleration vs. time graph, a velocity vs. time graph, a speed vs. time graph, a displacement vs. time graph, and a distance vs. time graph for the ball for both the horizontal direction and the vertical direction.

7. Abraham throws a ball horizontally eastward with an initial speed of 22 m/s from 830 meters above the surface of the Earth.
   a. Complete the table:

$x_{\mathrm{i}} =$ $v_{\mathrm{i,x}} =$ $a_{\mathrm{x}} =$	$y_{\mathrm{i}} =$ $v_{\mathrm{i,y}} =$ $a_{y} =$

   b. How long will the ball be in the air for after it is thrown?

   c. What will be the range of the ball?

   d. How long does it take for the ball to reach 400 m above the surface of the Earth after it is thrown?

   e. How high above the surface of the Earth will the ball be eight seconds after it is thrown?

   f. How far horizontally does the ball travel during the first eight seconds after it is thrown?

g. What will be the velocity of the ball (number and direction) eight seconds after it is thrown?

h. What will be the displacement of the ball (number and direction) eight seconds after it is thrown?

8. Lot throws a ball at an initial speed of 12 m/s at an angle of 30° south of east from 830 meters above the surface of the Earth.

   a. Complete the table:

$x_{\mathrm{i}} =$	$y_{\mathrm{i}} =$
$v_{\mathrm{i,x}} =$	$v_{\mathrm{i,y}} =$
$a_{\mathrm{x}} =$	$a_y =$

   b. How long will the ball be in the air for?

   c. What will be the range of the ball?

   d. How long after the ball is thrown does it take to reach 400 m above the surface of the Earth?

   e. How high above the surface of the Earth will the ball be four seconds after it is thrown?

   f. How far horizontally does the ball travel during the first four seconds after it is thrown?

g. What will be the velocity of the ball (number and direction) four seconds after it is thrown?

h. What will be the displacement of the ball (number and direction) four seconds after it is thrown?

9. A 25 kg ball is thrown from the edge of a very tall building with an initial speed of 20 m/s at an angle of 60° north of east. There is an infinitely tall vertical wall 120 m from the building.

   a. Draw a figure.

   b. Complete the table:

$x_{\mathrm{i}} =$	$y_{\mathrm{i}} =$
$v_{\mathrm{i,x}} =$	$v_{\mathrm{i,y}} =$
$a_{\mathrm{x}} =$	$a_y =$

   c. How much time does it take for the ball to hit the wall?

   d. At which height above or below the original position where the ball is thrown will the ball hit the wall?

   e. What will be the velocity of the ball (number and direction) when it hits the wall?

f. What will be the displacement of the ball (number and direction) when it hits the wall?