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"What one man calls God, another calls the laws of physics."

-Nikola Tesla

TOPIC 2: KINEMATICS

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THE ABOUT

CHAPTER ANALYSIS

TIME

- 4 **key** concepts
- Displacement, Velocity, Average Speed, Acceleration
- 2 **advanced** concepts
- Graphical Analysis, Free Fall

EXAM

- Tested in MCQ and Section A or B
- Important chapter that is closely linked to chapters like Force, Work Energy Power.

WEIGHTAGE

- Medium overall weightage
- Constitute to around **3.5%** of marks for past 5 year papers

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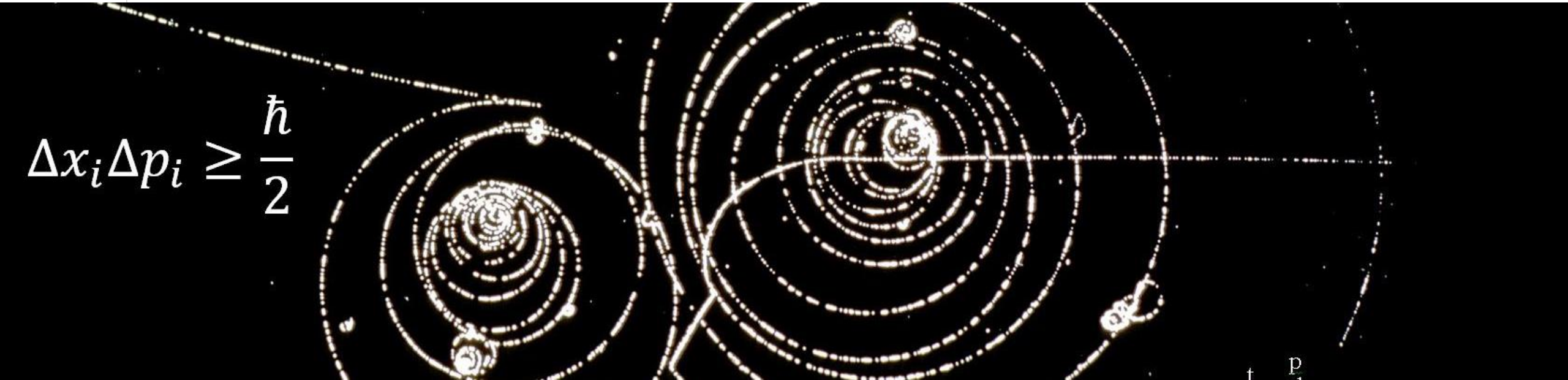
KEY CONCEPT

TWO PHYSICAL QUANTITIES
DISTANCE
DISPLACEMENT

$$\Delta x_i \Delta p_i \geq \frac{\hbar}{2}$$



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DISTANCE

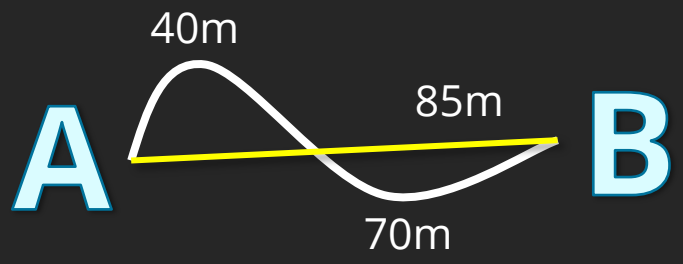
Distance is defined as the **total length travelled**, regardless of the direction of the motion.

Distance is a **scalar** quantity.

A scalar is a physical quantity that has **magnitude only**.

Unit: m

If a man walk along the curved path from point A to point B,



Total Distance:
40m + 70m = 110 m

DISPLACEMENT

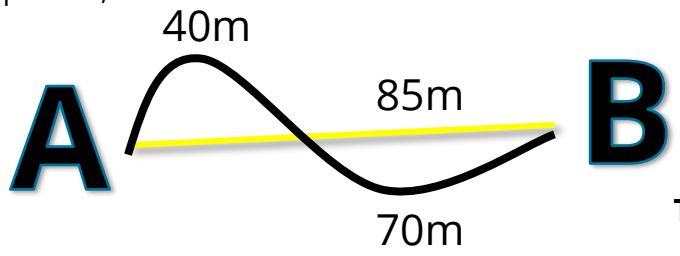
Displacement is defined as total length between the **start point** and the final **end point** of the object, taking into account the direction of the motion.

Displacement is a **vector** quantity.

A vector quantity is a physical quantity that have both **magnitude & direction.**

Unit: m

If a man walk along the same curved path from point A to point B,



Total Displacement:
85 m

So even though the man had travelled 110m, his displacement is only effectively 85m.

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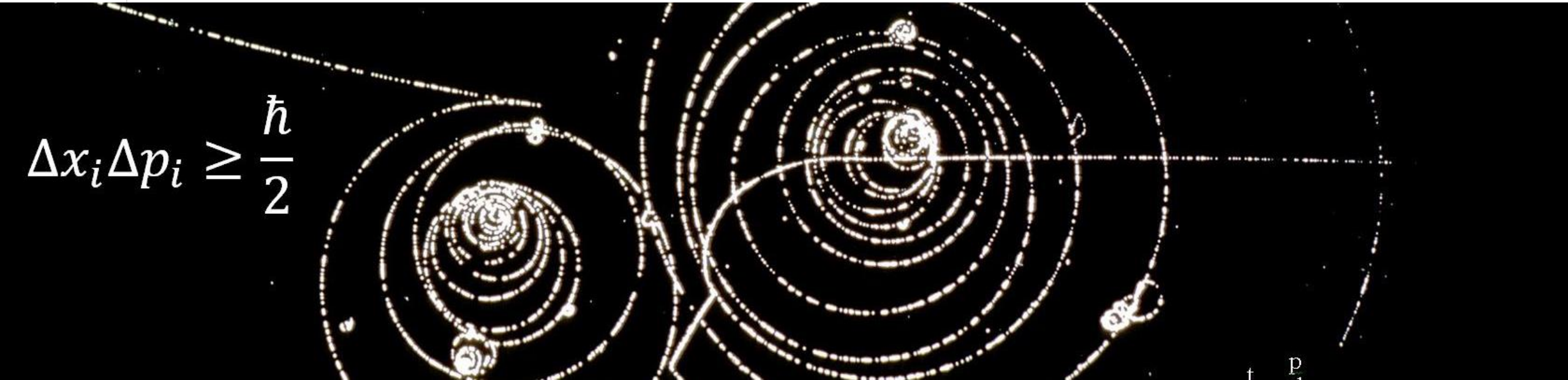
KEY CONCEPT

TWO PHYSICAL QUANTITIES
SPEED
VELOCITY



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SPEED

Speed is defined as the **rate of change of distance** with respect to time.

Speed is a **scalar** quantity & has no direction.

Unit: ms^{-1}

VELOCITY

Velocity is defined as the **rate of change of displacement** with respect to time.

Velocity is a **vector** quantity, that have both **magnitude & direction.**

Unit: ms^{-1}

EXAMPLE

Amy & David walk towards each other. Taking the direction to the left as positive,

Amy, 25s

Amy's speed:
100m / 25s = 4 ms^{-1}

Amy's velocity:
100m / 25s = 4 ms^{-1}

David, 30s

David's speed:
120m / 30s = 4 ms^{-1}

David's velocity:
-120m / 30s = -4 ms^{-1}

When calculating velocity, always take into account the direction!

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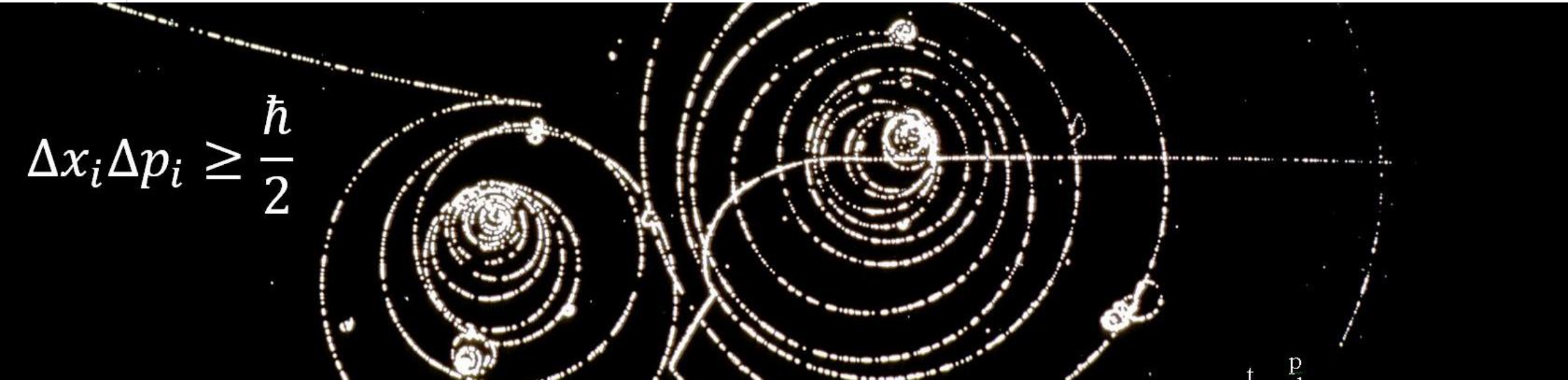
ADVANCED CONCEPT

AVERAGE SPEED ACCELERATION



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Average Speed

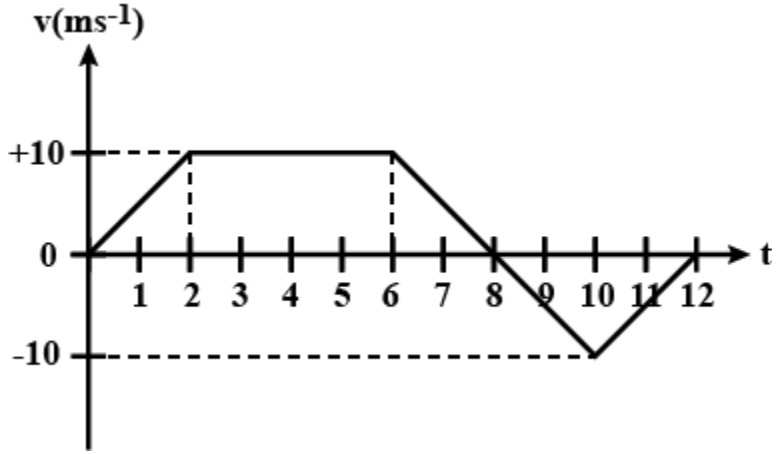
Average speed is the total distance travelled over a period of time.

Formula:

Average Speed = Total Distance / Total Time

Instantaneous speed is the speed at a specific point in time.

Average Speed Question



What is the average speed of the car?

Total Distance = Area under graph
= (½ x 2 x 10) + (4 x 10) + (½ x 2 x 10) + (½ x 4 x 10)
= 80m

Average speed = 80m / 12s
= 6.67 ms^{-1}

*Area of graph in negative region is in the **reverse direction**!

What is the average velocity of the car?

Total Displacement = area under graph
= (½ x 2 x 10) + (4 x 10) + (½ x 2 x 10) - (½ x 4 x10)
= 40m

Average velocity = 40m / 12s
= 3.33 ms^{-1}

What is the instantaneous speed of the car at 1s?

The instantaneous speed of the car at 1s is 5 ms^{-1} .

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Acceleration

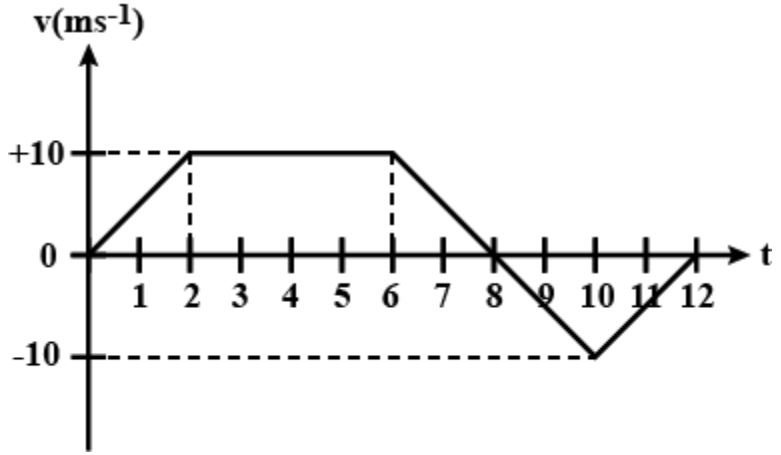
Acceleration is the **rate of change of velocity** with respect to time.

Formula:

Acceleration = Change in velocity / time

a = (v-u) / t

Acceleration Question



What is the acceleration of the car in the first 2 seconds?

Acceleration = (v-u) / t
= (10-0) / 2
= 5.0 ms^{-2}

What is the acceleration of the car between 2s - 6s?

The car is travelling at constant velocity, hence there is no acceleration.

Describe what is happening to the car from 6s to 12s.

From 6s to 8s, the car starts to decelerate, reducing its velocity from 10ms^{-1} to 0ms^{-1}.

At the 8s mark, the car is at rest momentarily before moving in the opposite direction. As it is reversing, it speeds up to reach -10ms^{-1}.

At 10s, the car slows down while traveling in the opposite direction before coming to rest at 12s.

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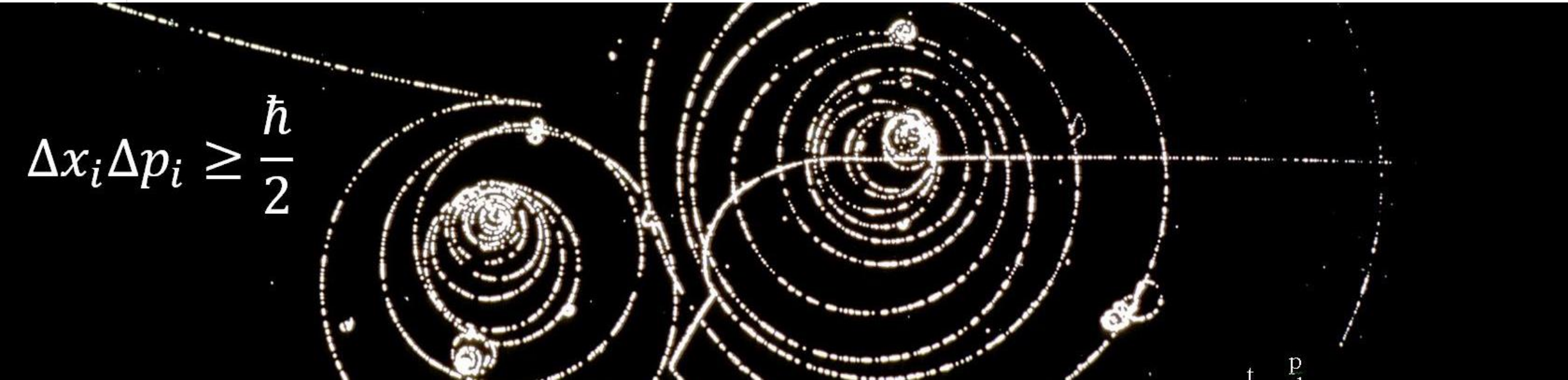
KEY CONCEPT

GRAPHICAL ANALSIS
DISPLACEMENT-TIME GRAPH
VELOCITY-TIME GRAPH



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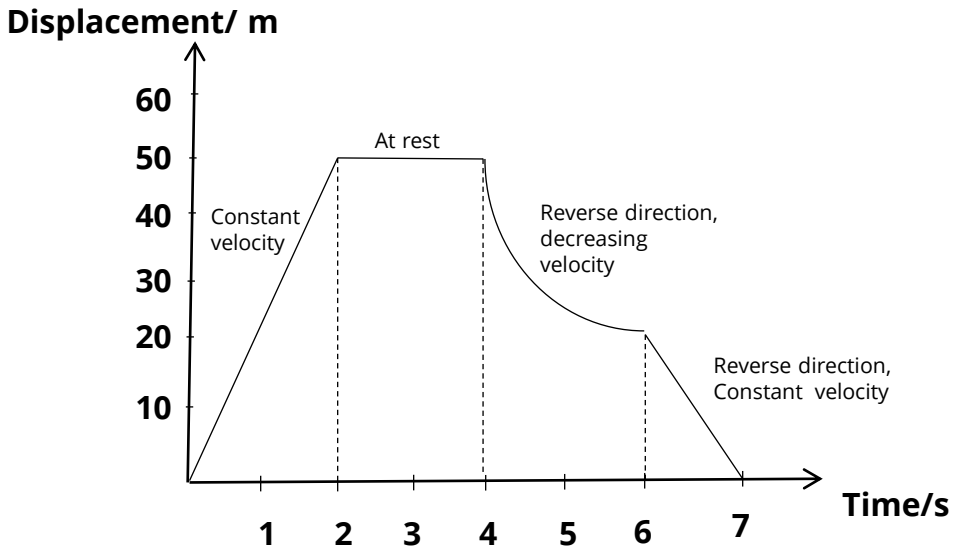
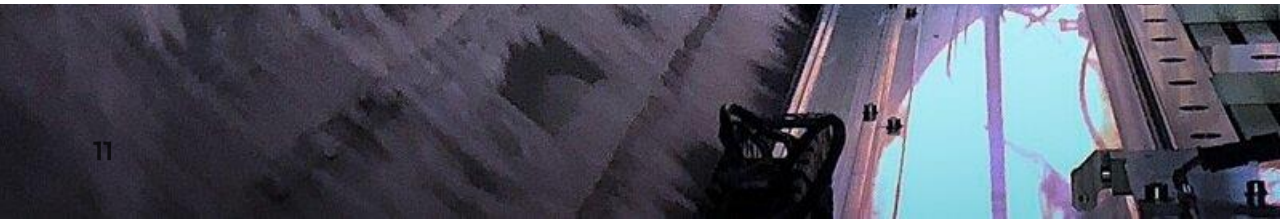
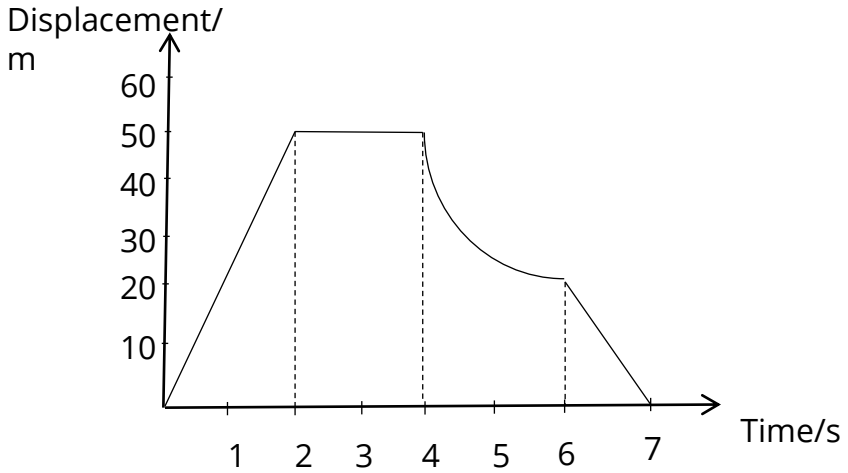
Displacement-time graph

Gradient represents **velocity** (change in displacement per unit time).





Displacement-Time Graph Question



What is the velocity of the car in the first 2s?

Velocity = gradient
= (50-0) / 2
= 25 ms^{-1}

What is the average speed of the car?

Average speed = Total Distance / Total Time
= (50m + 50m) / 7s
= 14.29 ms^{-1}

What is the average velocity of the car?

Average speed = Total Displacement / Total Time
= 0m / 7s
= 0 ms^{-1}

By referring to the Y-axis, at the end of the journey at 7s, the car's displacement is at 0m.

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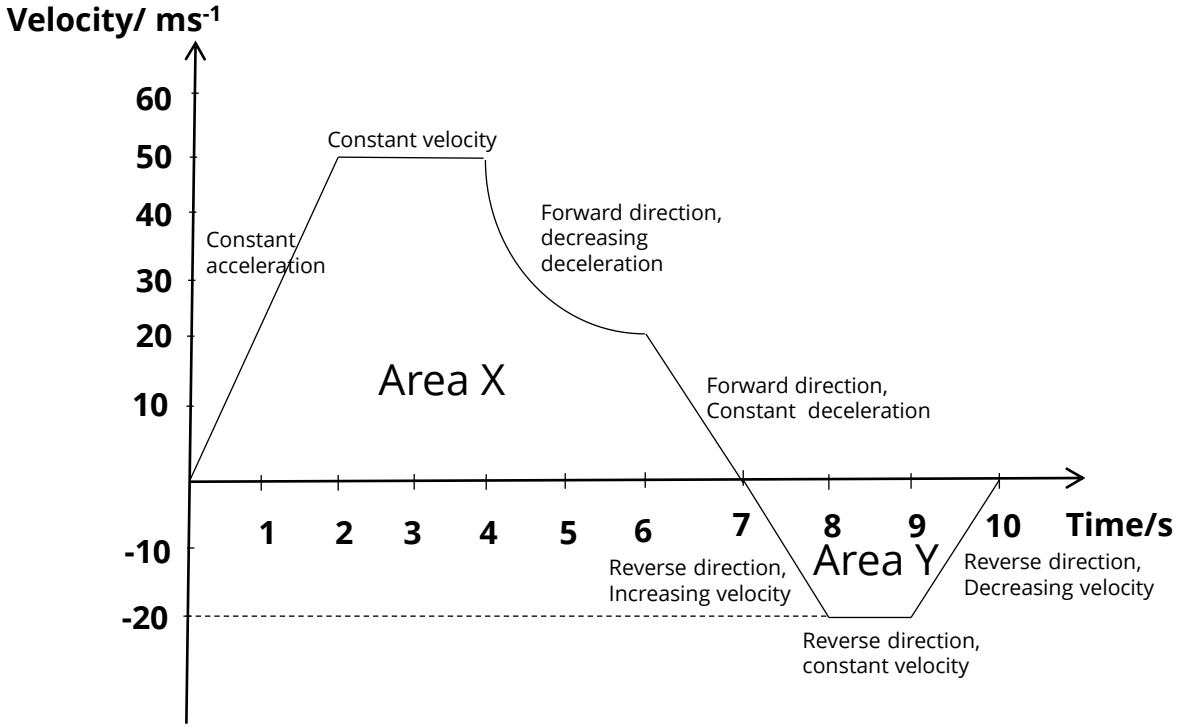
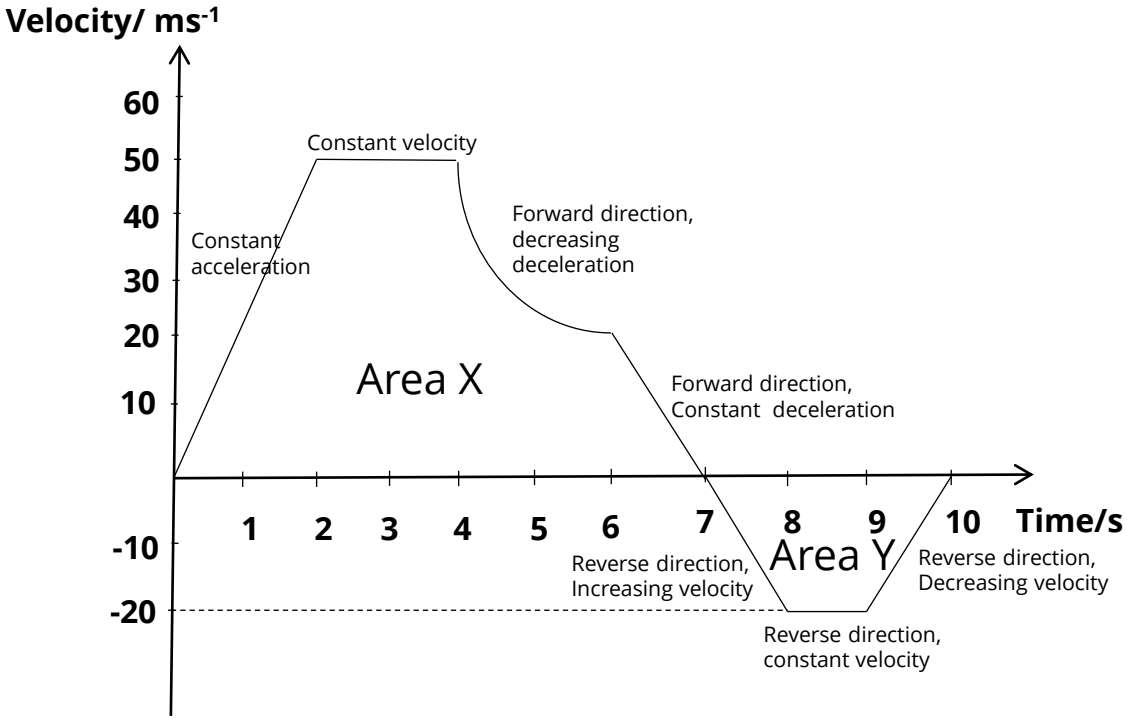
Velocity-time graph

Gradient represents **acceleration** (change in velocity per unit time).

Area underneath velocity-time graph represents **displacement.**



Velocity-Time Graph Question



What is the average velocity of the car?

Average velocity = Total Displacement / Total time
= *Area X* – *Area Y* / time

What is the average speed of the car?

Average speed = Total Distance / Total Time
= *Area X* + *Area Y* / time

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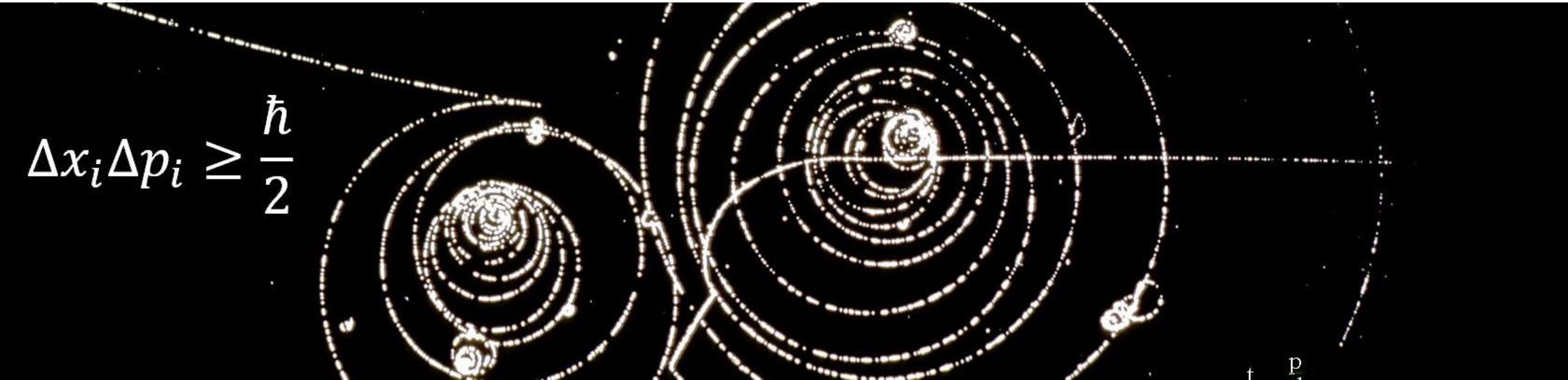
ADVANCED CONCEPT

NEWTON MECHANICS EQUATIONS

(Not in syllabus but very useful)

$v = u + at$
$s = 1/2\ (u + v)t$
$v^2 = u^2 + 2as$
$s = ut + 1/2\ at^2$



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Newton Mechanics

The formulas below are very helpful when it comes to solving certain questions.

Which formula to use depends on what variable is provided by the question.

$v = u + at$
$s = 1/2\ (u + v)t$
$v^2 = u^2 + 2as$
$s = ut + 1/2\ at^2$

Alternatively, if this is too complicated, questions can still be solved by drawing the graph and working out the solution accordingly.

But as you can see in the example later, the graphical method is more tedious and can get complicated. → *Using graphical method,*

A car moves forward at a initial velocity of 80 ms^{-1}. It then decelerate at a constant pace of 4.0 ms^{-2} until it comes to rest. (Final velocity = 0 ms^{-1})

How long does the car take to come to rest?

Using **$v = u + at$,**

$0 = 80 + -4(t)$
$t = 20s$

What is the total distance travelled by the car?

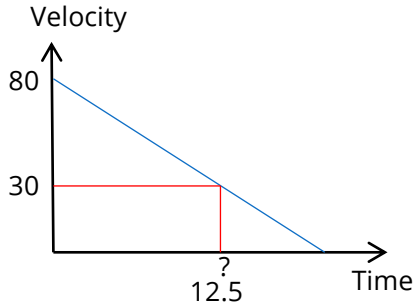
Using **$s = ut + 1/2\ at^2$,**

$s = 80(20) + ½(-4)(20)^2$
$s = 800m$

What is the distance travelled by the car when its velocity is 30ms^{-1}?

Using **$v^2 = u^2 + 2as$,**

$30^2 = 80^2 + 2(-4)(s)$
$s = 687.5m$



First we have to find the time at instantaneous velocity 30ms^{-1}. (Deceleration is -4 ms^{-1})
$a = (v-u) / t$
$-4 = (30-80) / t$
$t = 12.5s$

Distance travelled = **area under graph** (trapezium)
$= ½ \times (80+30) \times 12.5$
$= 687.5m$

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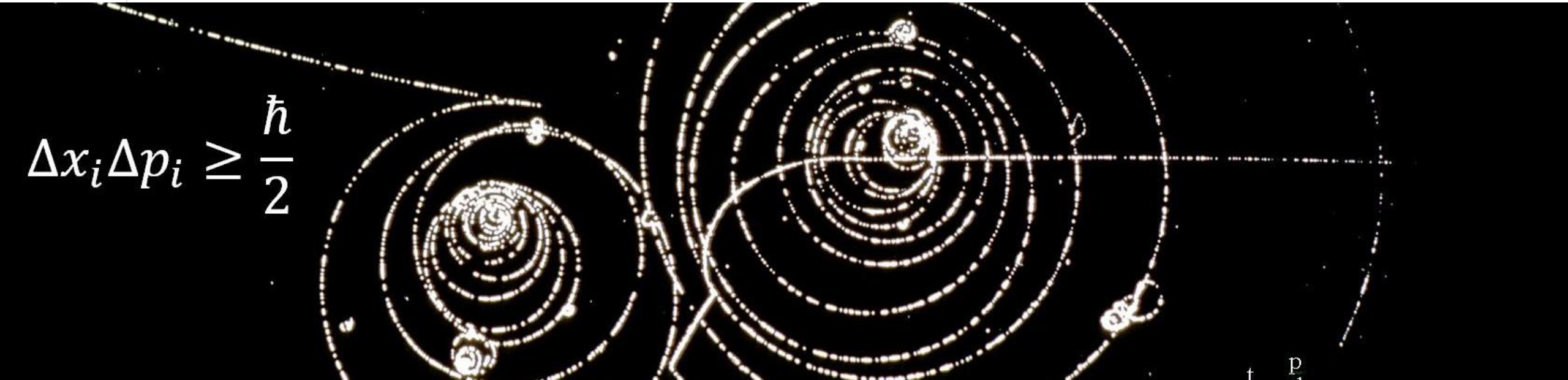
ADVANCED CONCEPT

Acceleration of free fall, g
Air Resistance
Terminal Velocity



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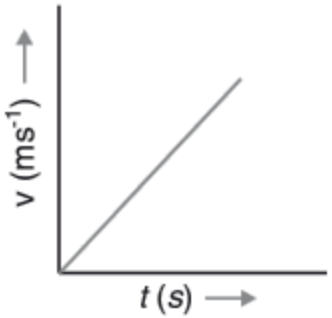
Acceleration of free fall

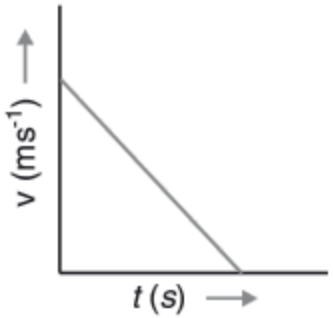
As all objects have mass, they will experience a **gravitational force**. Free fall occurs when an object falls under the sole influence of gravity (no air resistance).

$g = 10 ms^{-2}$

For object falling in mid-air,



For object thrown vertically upwards,



Air Resistance

Air resistance is a frictional force that opposes the motion of moving objects due to collision with air particles present in the air.

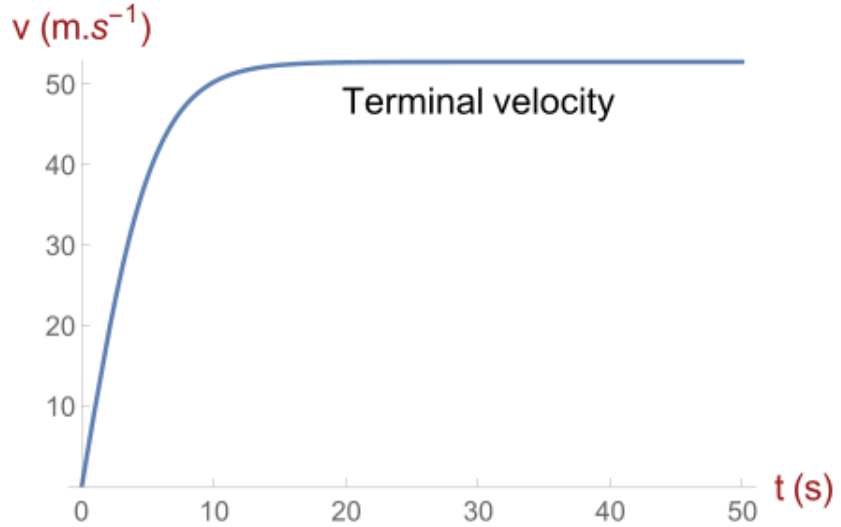
Air resistance increases with the speed/surface area of the object.

Terminal Velocity

Air resistance increases when velocity increases. Therefore when an object falls through a long distance in air, eventually **the air resistance will be equal to the weight of the object**.

The **resultant force on the body is zero and there will be no acceleration** . (F=ma)

The object will then continue its fall at constant velocity. This constant velocity is also known as **terminal velocity**.



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