O Level Physics
Unit 2: Kinematics

1. Scalar and Vector quantities

	Type of Quantity	
	Scalar	Vector
By definition	Has magnitude only	Has magnitude and direction.
Examples	Distance Speed Time Mass	Displacement Velocity Acceleration Weight

Displacement is distance in a specified direction.

Note: When asked to find
a) a scalar quantity, only the magnitude is required (e.g. 70m).
b) a vector quantity, the magnitude and direction are required. (e.g. 75m, 20° from the North.

2. Kinematic Quantities

	Symbol	SI Unit
Time	t	s
Distance/Displacement	s	m
Speed/Velocity	v	m/s
-Final velocity	v	m/s
-Initial velocity	u	m/s
Acceleration	a	m/s^2

Speed and Velocity

3.

	Speed	Velocity
Definition	Distance travelled per unit time.	Change in displacement per unit time.
Type of quantity	Scalar	Vector
SI Unit	m/s	
Formula	$v = \frac{distance}{t}$	
Note	The magnitude of the speed and velocity of an object will differ if there is a change in direction.	

4. Two moving objects are said to have the same velocity when they have the same speed and move in the same direction. In a linear motion, velocity can be positive or negative to specify the direction of motion denoted as positive and negative. A positive velocity describes motion in the denoted positive direction; and negative velocity in the denoted negative direction (or back towards starting point)

Note: In negative velocity (e.g. -6m/s), the negative sign = motion opposite to the positive direction denoted. However, its speed is 6m/s as speed is a scalar and does not involve direction.

Acceleration

5.

	Acceleration
Definition	Change in velocity per unit time.
SI unit	m/s^2
Type of Quantity	Vector
Formula	Acceleration = $\frac{\text{change in velocity}}{\text{time}}$ $a = \frac{v-u}{\Delta t}$

Note: The formula may be changed to the following:

a) $\mathbf{a = \frac{v-u}{\Delta t}}$
b) $\mathbf{v = u + a(\Delta t)}$
c) $\mathbf{\Delta t = \frac{v-u}{a}}$

6. Acceleration occurs when there is a change in an object's velocity (change in speed and/or direction).

7. Positive acceleration: Object accelerates in direction of velocity. Hence, velocity is increasing.
Negative acceleration: Object accelerates in direction opposite to velocity. Hence, velocity is decreasing.

For a linear motion, the direction of the acceleration can be specified by denoting as positive and negative.

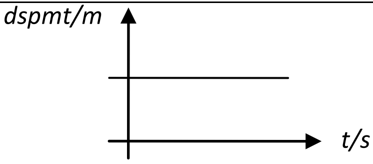
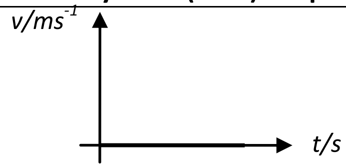
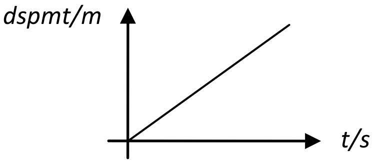
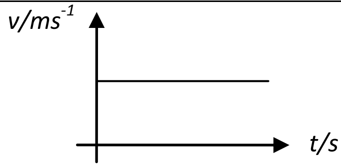
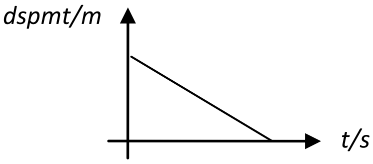
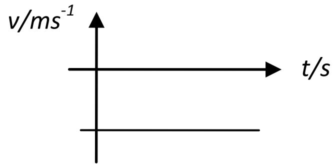
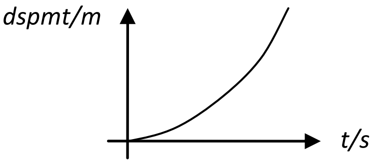
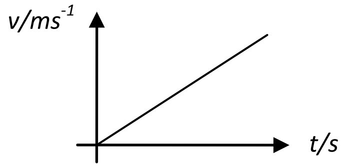
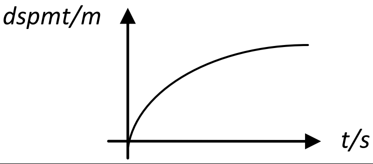
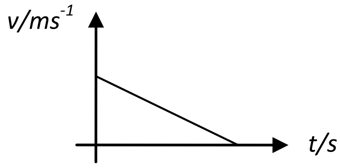
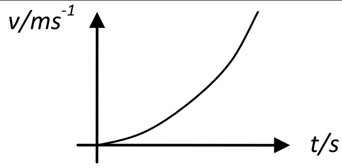
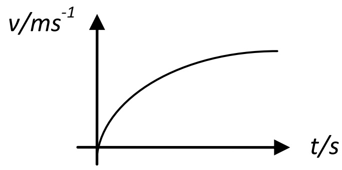
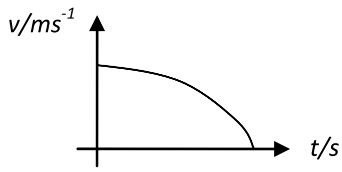
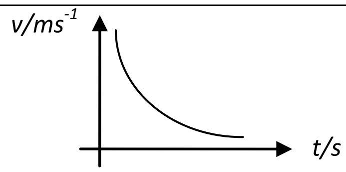
Note: When objects travel in a non-linear motion, it undergoes positive acceleration.

Graphical Analysis of Motion

8. Deductions of graphs

	Displacement-time (disp-t) graph	**Velocity-time (vel-t) Graph**
Deductions	• The gradient of the d-t graph is equivalent to the speed OR velocity. [See note] • A st line with positive grad ⇒ uniform velocity; st line with negative grad ⇒ uniform velocity in opposite direction. • Curve ⇒ non-uniform velocity (positive acceleration) • Grad of the tangent at a point ⇒ instantaneous speed OR velocity. [See note] Note: The grads of dist-t ⇒ speed; of dspmt-t ⇒ velocity. Distance & speed are scalars, displacement & velocity are vectors. Note that dspmt-t graph involves direction unlike dist-t.	• Grad of vel-t graph ⇒ acceleration. Positive grad ⇒ positive acc; negative grad ⇒ negative acc/deceleration (moving in opp direction) • St line ⇒ uniform acc; curve ⇒ non-uniform acc (positive) • Grad of the tangent at a point ⇒ instantaneous acc. • Area under the graph ⇒ distance travelled OR displacement [See note].

9. Summary- Graphical Analysis of Motion

	Displacement-time (disp-t) graph	**Velocity-time (vel-t) Graph**
At rest		
Uniform velocity		
*Uniform velocity in opposite direction	*Note: Not applicable for distance-time graph. 	*Note: Not applicable for speed-time graph. 
Uniform acceleration (just acceleration for disp-t)		
Uniform deceleration (just deceleration for disp-t)		
Increasing acceleration		
Decreasing acceleration		
Increasing deceleration		
Decreasing deceleration		

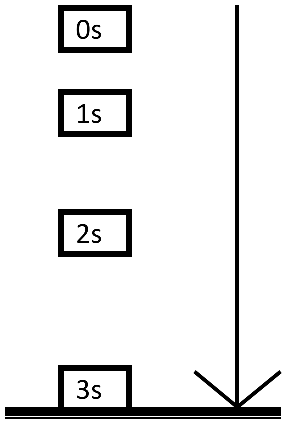
<u>Acceleration of Free Fall</u>

10. During free fall when there is no air resistance, all objects falling under gravity experiences constant acceleration (acceleration due to gravity). The acceleration due to gravity, g, for a body close to Earth's surface is a constant $10m/s^2$. Every one second, the object's speed will increase by 10m/s.

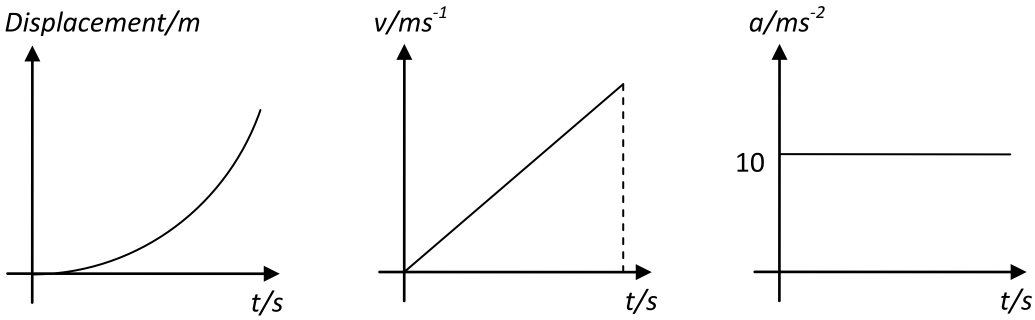
Acceleration due to gravity where air resistance is negligible is independent of mass and surface area. All objects undergo the same constant acceleration.

$g = \frac{v-u}{\Delta t}$ is equivalent to $10 = \frac{v-u}{\Delta t}$;
W=mg is equivalent to W=m(10) , since the constant g is known.

11. Free fall- Downward motion

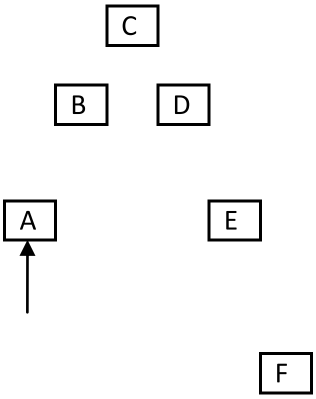


Dspmt		Vel/ms^{-1}	g/ms^{-2}	
0m	0s	0	10	At the moment when object was dropped, it was at rest.
10m	1s	10	10	Object accelerates due to gravity at $10m/s^2$. In 1s, it travels 10m.
30m	2s	20	10	Object accelerates due to gravity at $10m/s^2$. In 1s, it travels 20m
50m	3s	0	0	Object at rest. Velocity and acceleration are both zero.

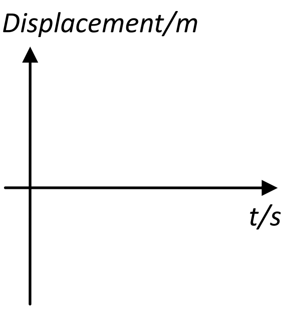


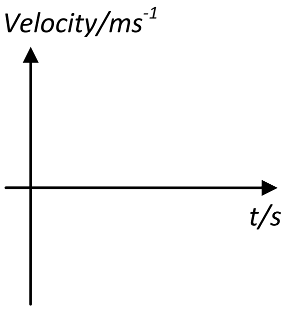
Area under velocity/speed - time graph= displacement/distance dropped respectively.

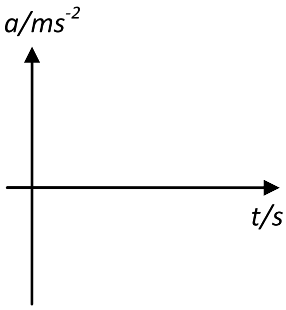
12. Free fall- Upward and downward motion.

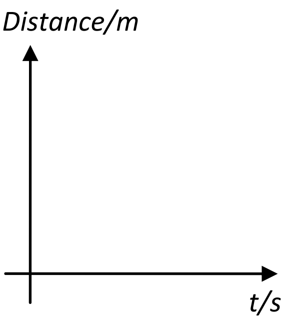


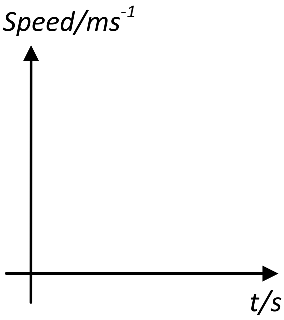
Pstn	Time	Vel/ms^{-1}	g/ms^{-2}	Dspmt/m
A	0s	-20	-10	0
B	1s	-10	-10	-20
C	2s	0	Non-zero	-30
D	3s	10	10	20
E	4s	20	10	0
F	5s	30	10	30











Area under velocity/speed-time graph = displacement/distance respectively.

Air resistance

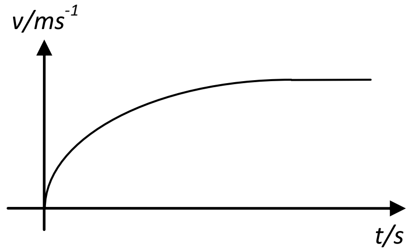
13. Air resistance is a frictional force which opposes motion. It causes the acceleration of an object in free fall to be lower than the acceleration of free fall.
(g of object falling with air resistance < $10m/s^2$)

An object falling under gravity with air resistance experiences decreasing acceleration (air resistance increases with increasing velocity) until terminal velocity is reached.

14. Air resistance is dependent on
   a) Velocity: Air resistance increases with velocity till terminal velocity.
   b) Surface area: Air resistance is directly proportional to the surface area of an object.

15. Terminal velocity is the maximum constant velocity that can be reached where a = 0 and which occurs when (weight = air resistance).
Terminal velocity is dependent on:
   a) Mass of object: A heavier object will experience a higher terminal velocity than a lighter object
   b) Surface area of object: An object with a larger SA will experience lower terminal velocity than one with a smaller SA.

16.



Decreasing acceleration due to increasing velocity hence increasing air resistance.

t/s	R and W	v/ms^{-1}	a/ms^{-2}	dspmt/m
0	R = W	0	0	0
1	$R_1 < W$	8	8	8
2	$R_2 < W$ $R_1 < R_2$	14	6	22
3	$R_3 < W$ $R_1 < R_2 < R_3$	18	4	30
4	R = W	20	0	32

Note: W is a constant, R increases with velocity.

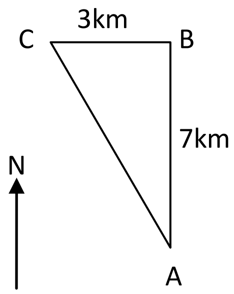
Questions involving calculations- Unit 2: Dynamics

Speed and Velocity

1. A car travels 7km north and then 3km west in 10mins. Calculate its
   a) average speed; b) average velocity.

a) Ave speed = $\frac{\text{Total distance}}{\text{Time}}$
= 60km/h

b) By Pythagoras' Theorem,
AC = $\sqrt{7^2 + 3^2}$
Displacement ≈ 7.6158km



Ave velocity = $\frac{7.6158}{\frac{1}{6}}$
= 45.7km/h (3sf)

Bearing of C from A = $360° - \left[\tan^{-1}\left(\frac{3}{7}\right)\right]$
= 336.8° (1dp)

Ave velocity is 45.7km/h, 336.8° from the North.

Acceleration

2. The figure shows the displacement-time graph of an object.

a) Fill in the table below and sketch the corresponding velocity-time graph.

Time	Displacement	Velocity
0 to 4s		
4 to 8s		
8 to 16s		

b) Calculate
   i) the average speed of the object
   ii) the average velocity of the object

c) If the object decelerates uniformly to rest in 8s at the end of the 16s, calculate the distance moved in this period.

3. A motorist, who saw the traffic light he was approaching turn red, was travelling at 15m/s. His reaction time is 0.4s.

a) Given that the maximum deceleration of the car is $3.75 m/s^2$, calculate the distance travelled by the car before it comes to a complete stop.

Given that the motorist is 40m away from the junction which he stopped exactly at, calculate

b) the car's deceleration.

c) the time taken for the car to stop, using your answer in (b).

<u>Acceleration of Free Fall</u>

4. A brick falls from the top of the building and takes 4.0s to reach the ground. Calculate

a) the speed of the brick when it reaches the ground;

b) the height from which it falls.

a) $g = \frac{v - u}{\Delta t}$

$10 = \frac{v - 0}{4}$

v = 10 x 4

= 40m/s

b) Height = distance travelled

= average speed x time

$= \frac{1}{2}(0 + 40)(4.0)$

=80m

5. A book was dropped from a window 9m above the ground. Calculate
   a) the time taken for the book to hit the ground
   b) the speed of the book when it hits the ground.

a) $g = \frac{v - u}{\Delta t}$

$10 = \frac{v - 0}{\Delta t}$

Final speed = 10t

Distance = average speed x time

$9 = \frac{1}{2}(10t) \times t$

$5t^2 = 9$

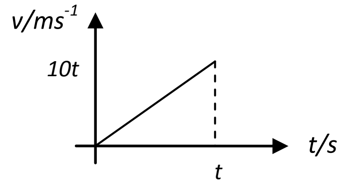
t = 1.34s

Alternative mtd for (a)

$g = \frac{v - u}{\Delta t}$

$10 = \frac{v - 0}{\Delta t}$

Final speed = 10t



Area under v-t graph = distance = $\frac{1}{2}vt = 5t^2$

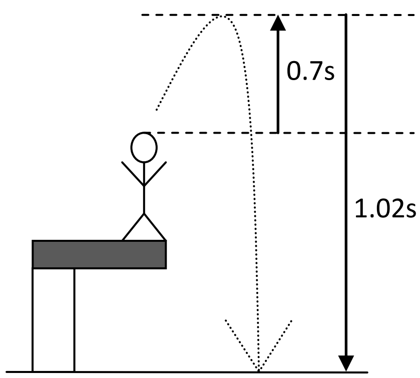
$5t^2 = 9$

t = 1.34s

b) Final speed = 10t

= 13.4m/s

6. A man takes off from a spring board as shown in the diagram. He jumps up into the air to reach the highest point of his jump before falling downwards. (Take air resistance as negligible).



   a) It is given that that the man took 0.7s to reach the highest point of his jump. Calculate his speed when he leaves the spring board.
   b) He takes another 1.02 before entering the water. Calculate his speed when he enters the water.
   c) Find the height of the springboard above the water.