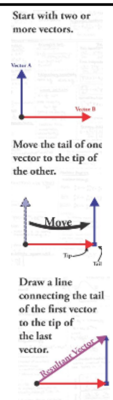
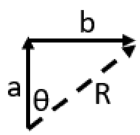
Subject: A-level Physics	Topic: Mechanics	Year Group: 12

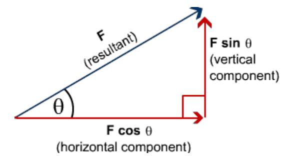
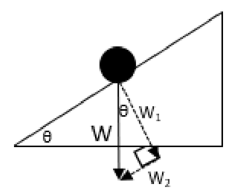
Scalars and vectors

1	Examples of scalars	Distance, speed, mass, temperature, time, energy.
2	Examples of vectors	Displacement, velocity, force, acceleration, momentum.
3	**Resultant vector** – the vector formed when two or more vectors are added together.	
4	To **find the resultant** of several vectors you can use a **scale drawing**.	
5	• Choose a scale and include a reference direction. Draw one vector as an arrow in the correct direction and of the correct length. • Do the same for each vector, each time starting from the head of the previous vector. In this way, the vectors to be added are drawn tail-to-head. • The resultant is the vector drawn from the tail of the first vector to the head of the last. Its magnitude = length of arrow. Its direction can be measured using a protractor.	
6	If two vectors are perpendicular to one another you can use trigonometry to determine the resultant. The size of the resultant is determined using Pythagoras, $R = \sqrt{a^2 + b^2}$ The size of the angle is given by, $\theta = tan^{-1}\left(\frac{b}{a}\right)$	

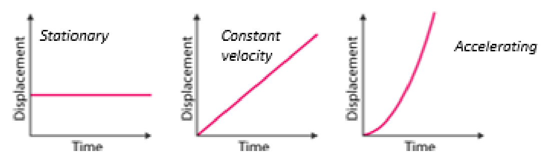
Equilibrium

1	If an object is in **equilibrium** the resultant force is 0 N.
2	The object is either stationary or moving at a constant velocity.
3	When the force arrows are drawn tip-to-tail they form a closed loop.

Resolving vectors

1	This is the splitting of a resultant vector into two components at right angles to one another.	
2	$Vertical\ component = Fsin\theta$ $Horzintal\ component = Fcos\theta$	
3	For objects on slopes you may need to resolve the vector into components parallel and perpendicular to the slope.	
4	W_1 is the component of W perpendicular to the plane. W_2 is the component of W parallel to the plane. Importantly the angle in the W, W_1, W_2 triangle is the same as the angle the slope makes with the horizontal. $W_1 = Wcos\theta$ $W_2 = Wsin\theta$	
5	Perpendicular components of vectors do not affect each other.	

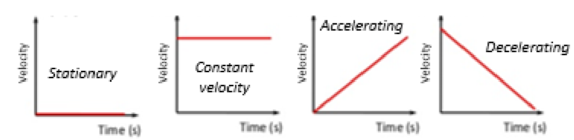
Displacement-time graphs

1		
2	The steeper the line, the faster the object. So for accelerating objects the gradient increases. For decelerating objects the gradient decreases.	
3	Gradient gives	Velocity
4	Gradient of tangent gives	Instantaneous velocity
5	Rate of change of gradient gives	Acceleration

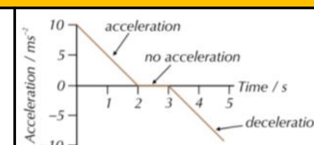
Key Vocabulary

1	Scalar	A quantity with a magnitude but no direction.
2	Vector	A quantity with a magnitude and a direction.
3	Displacement	How far an object has travelled from its starting point in a given direction.
4	Velocity	The rate of change of displacement.
	Instantaneous velocity	The velocity at a particular moment in time.
5	Acceleration	The rate of change of velocity.
6	Equilibrium	When all the forces acting on it are balanced and cancel one another one. The resultant force is 0 N.

Velocity-time graphs

1		
2	Velocity-time graphs go into the negative region when the object is travelling in the opposite direction.	
3	A curve of increasing gradient means the rate of acceleration is increasing.	
4	Gradient gives	Acceleration
5	Area under graph gives	Displacement

Acceleration-time graphs

1	Any line above the time axis means the object is accelerating (even if the gradient is negative).	
2	Area under graph gives	Total change in velocity

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Uniform acceleration (SUVAT)

1	The SUVAT equations can only be used for motion along a straight line with CONSTANT acceleration.

2

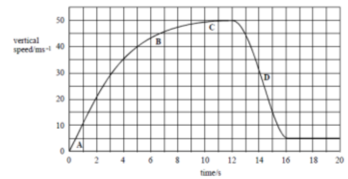
Symbol	Quantity	SI unit
s	Displacement	m
u	Initial velocity	ms^{-1}
v	Final velocity	ms^{-1}
a	Acceleration	ms^{-2}
t	Time	s

3 Things to remember:
- If the object starts at rest then u = 0 ms^{-1}.
- Often the acceleration will be g = 9.81 ms^{-2}.
- You decide which direction is positive. If the object is moving downwards it often makes sense to take downwards as positive in which case g = +9.81 ms^{-2}.

Newton's laws

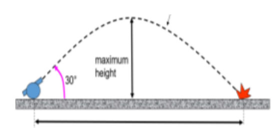
1	See definitions in key vocabulary box.	
2	Newton's 1st law	Means an object will remain stationary or moving at a constant speed until a resultant force acts.
3	Newton's 2nd law	In equation form we can write, $F = ma = \frac{\Delta(mv)}{\Delta t}$ Where Δ(mv) is the change in momentum in $kgms^{-1}$ and **Δ(mv) = mv – mu**.
4	Newton's 3rd law	Example – when swimming your arms push back against the water, the water pushes you forwards with an equal and opposite force.

Terminal velocity

1	In fluids friction is called drag. The amount of drag depends on,	• The viscosity of the fluid. Thicker fluid = more drag. • Speed. Faster objects hit more fluid particles each second = more drag. • Object's surface area. The larger the surface area, the more fluid particles it hits each second meaning drag is greater.
2	This shows how the vertical speed of a parachutist changes with during the first 20 seconds.	

3	A	<u>Uniform</u> acceleration as the only force acting on the parachutist is their weight.
	B	Speed still increasing but acceleration is decreasing because drag becomes greater at higher speeds.
	C	Uniform speed because resultant force on parachutist is zero as weight is balanced exactly by drag.
	D	Parachute has been opened, increasing drag so drag is larger than weight and he decelerates.
	E	(Flat section). Drag has decreased because as he slows he hits fewer air particles per second. Now reached a new terminal speed as drag and weight once again balance.

Projectile motion

1	Horizontal and vertical components of motion are independent.	
2	Resolve velocity into the vertical and horizontal components. Use the vertical component and SUVAT equations (a = g) to work out how long it is in the air, t. Use horizontal component to determine range using d = s x t.	 Range
3	When air resistance is not ignored it, - Reduces the horizontal speed, reducing the range. - If the projectile has a vertical component of velocity, the maximum height is reduced and the angle of descent steepens.	

Key Equations

1	SUVAT	$v = u + at$ $s = \frac{1}{2}(v+u)t$ $v^2 = u^2 + 2as$ $s = ut + \frac{1}{2}at^2$
2	Newton's second law	$F = ma = \frac{\Delta(mv)}{\Delta t}$
3	Impulse	$Impulse = F\Delta t = \Delta(mv)$

Key Vocabulary

1	Newton's first law	The velocity of an object will not change unless a resultant force acts on it.
2	Newton's second law	The acceleration of an object is directly proportional to the resultant force acting on it when the mass of the object is constant.
3	Newton's third law	If object A exerts a force on object B, then object B exerts an equal and opposite force on object A.
4	Terminal velocity	The velocity at which the driving force matches the frictional force.
5	Impulse	The product of force and time.

Impulse and Newton's 2nd law

1	Impulse equals change in momentum. The units are **Ns**.
2	Impulse is given by the **area under a force-time graph**.
3	From Newton's 2nd law we can see that to reduce the force of an impact you need to increase the time for the impact.
4	Eggs are placed in a container that crumples on impact as the egg is then effectively stopped in a longer distance, hence greater time and therefore there is less force on the egg (less likely to break).
5	Similarly cars have crumple zones to increase the time it takes the car to come to a stop, increasing impact time and decreasing the force on the passengers.

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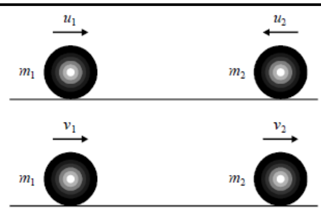
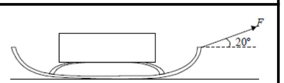
Momentum and collisions

1	The larger an object's momentum, the harder it is to stop.	
2	Momentum is a vector so it can be positive and negative.	
3	The principle of the conservation of momentum says, $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$	
4	The conservation of momentum is the reason an air riffle recoils when fired. Before it is fired the initial momentum is 0. Therefore the momentum of the system must be 0 afterwards too. The forward momentum gained by the pellet is equal in size but opposite in direction to the backwards momentum of the riffle.	

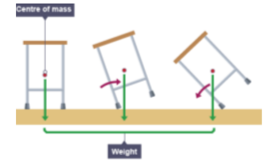
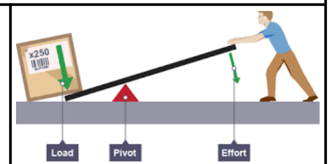
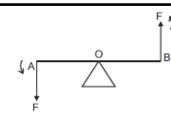
5

	Mass	Momentum	Kinetic energy	Total energy
Elastic	Conserved	Conserved	Conserved	Conserved
Inelastic	Conserved	Conserved	Not conserved	Conserved

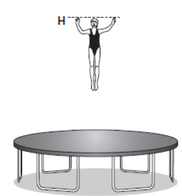
Work and power

1	**W = Fs** W = work done (J), F = force **that is in the same direction as the movement** (N), s = distance moved (m).	
2	Here a sledge is moving horizontally. You would need to work out the horizontal component of F to determine the work down in pulling the sledge.	
3	More generally, for a force at an angle to the direction of motion, $W = Fs\cos\theta$ Where θ is the angle at which F acts from the direction of motion.	
4	The area under a force-displacement graph gives the work done. You need to use this method when the value of F is changing as you cannot use the equation $W = Fs\cos\theta$ in this case.	

Moments

1	The object on the far right will topple over because the line of action of its weight falls outside of its base area. The higher the mass and smaller the base, the more unstable the object.	
2	**Moment (Nm) = force (N) x perpendicular between the force and turning point (m)**	
3	In a lever an effort forces acts against a load force. Levers create large turning effects by increasing the distance between the effort force and the pivot.	
4	Couple = pair of forces of equal size which act parallel to each other in opposite directions.	
5	**Moment of a couple** - one **force × perpendicular** distance between the two **forces**.	

Conservation of energy

1	Energy cannot be created or destroyed, only transferred.	
2	You may be asked to describe energy transfers in particular situations.	
3	Here as the girl moves from height H, down and back up to H, • GPE goes to KE and then to elastic potential • Elastic potential then goes to KE then to GPE • Energy is lost due to work done on air / trampoline • Work done by child (on trampoline) makes up for energy losses	
4	If a car crashes lots of kinetic energy is transferred in a short amount of time. Cars are designed to transfer some of this kinetic energy into other forms. For example, crumple zones absorb some of the kinetic energy when they deform.	

Key Equations

1	Momentum	$p = mv$
2	Work done	$W = Fs\cos\theta$
3	Power	$P = \frac{E}{t} = \frac{W}{t}$
4	Power	$P = Fv\cos\theta$
5	Kinetic energy	$E_K = \frac{1}{2}mv^2$
6	Gravitational potential energy	$\Delta E_p = mg\Delta h$
7	Elastic potential energy	$E = \frac{1}{2}k(\Delta L)^2$
8	Efficiency	$= \frac{useful\ energy\ out}{total\ energy\ in} = \frac{useful\ power\ out}{total\ power\ in}$
9	Moment	$Moment = Fd$

Key Vocabulary

1	Momentum	The product of mass and velocity of an object.
2	Conservation of momentum	The total momentum before a collision is the same as the total momentum after a collision provided no external forces act on the system.
3	Inelastic collision	A collision in which kinetic energy is not conserved.
4	Conservation of energy	Energy cannot be created or destroyed. It can be transferred from one form to another but the total amount of E in a closed system remains constant.
5	Work done	The energy transferred from one form to another when a force causes movement.
6	Moment	The product of the force and the **perpendicular distance** from the pivot.
7	Principle of moments	Sum of clockwise moments = sum of anticlockwise moments, for a body in equilibrium.
8	Couple	A pair of forces of equal size which act parallel to each other in opposite directions.