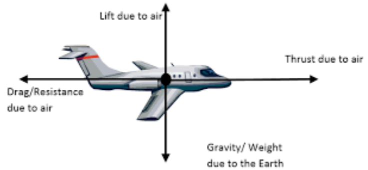
SP2 Forces and Motion

Lesson sequence

1. Resultant forces
2. Newton's first law
3. Mass and weight
4. Newton's second law
5. Core practical – investigating acceleration (CP12)
6. Newton's third law
7. Momentum (HT ONLY)
8. Stopping distances
9. Car safety
10. Braking distance and energy (TRIPLE ONLY)

1.Resultant forces

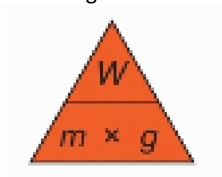
Scalar quantity	A quantity with magnitude (but no direction).
Vector quantity	A quantity with magnitude and direction.
Force arrows	Arrows can be used to represent forces: - Direction = direction of force - Length = size of force
Resultant force	The force left over when forces acting in opposite directions are cancelled out.
Calculating resultant force	Subtract the total force in one direction from the total force in the other direction.
Balanced forces	When the resultant force is zero (because forces acting in opposite directions are the same size).
Unbalanced forces	When the resultant force is non-zero (because there is more force in one direction than another).



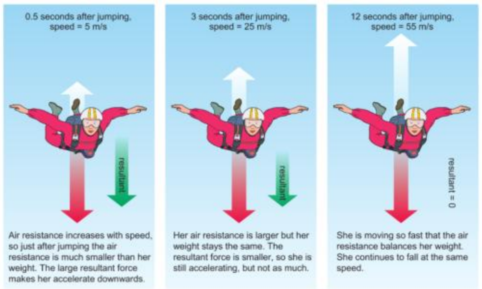
2. Newton's first law

Newton's first law of motion	An object will move at the same speed and direction unless it experiences a resultant force.
The effect of resultant forces	Resultant forces cause acceleration: speeding up, slowing down or changing direction
The effect of forces on motion	Forces make you start moving, stop moving or change direction, they are not needed to keep you moving!

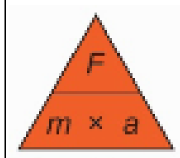
3. Mass and weight

Mass	The quantity of matter in an object is made of. Units = kilograms (kg)
Weight	A force caused by gravity pulling downward on an object. Units = newtons (N)
Force meter	An instrument for measuring forces. They usually have a spring that stretches more the greater the force applied.
Gravitational field strength	The strength of gravity, which is different on different planets. Units = newtons per kilogram (N/kg)
Gravitational field strength on Earth	10 N/kg
Calculating weight	Weight = mass x gravitational field strength W = m x g  Weight (N) Mass (kg) Gravitational field strength (N/kg)

Air resistance	A force caused by the air pushing against you as you move. Faster movement → greater air resistance.
Motion whilst falling	Falling objects accelerate until the air resistance is equal to the weight; now there is no resultant force so speed stays constant (**terminal velocity**).

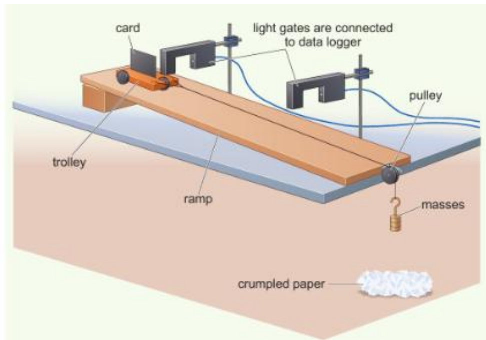


4. Newton's second law

Newton's second law of motion	Force = mass x acceleration
Acceleration is greater when…	- The force is greater - The mass is smaller
Calculating forces	Force = mass x acceleration F = m x a  Force (N) Mass (kg) Acceleration (m/s^2)
Calculating acceleration	Acceleration = mass / force a = F / m Force = N Mass = kg Acceleration = m/s^2

5. Core practical – investigating acceleration (CP12)

CP12 - Aim	To investigate how changing force changes acceleration.
CP12 - Setup	A trolley on a ramp with 9 x 10g masses. 10 g mass hanger attached to trolley via a string over a pulley.
CP12 – Data collection	Release the trolley, use light gates to measure the acceleration.
CP12 – Variations	Move 10 g of mass from the trolley to the mass hanger each time.
CP12 – Independent variable	The force: each 10 g mass = 0.1 N force
CP12 – Control variables	Move the 10 g masses from the trolley to the mass hanger to keep the total mass in the system the same. Raise the ramp slightly until the car only just starts to move freely to eliminate the effects of friction.
CP12 - Results	More mass pulling on the string → more force → greater acceleration.

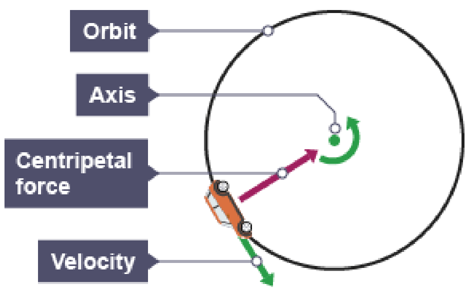


6. Newton's third law	
Newton's third law	For every action force there is an equal but opposite reaction force.
Action force	The force you push or pull with.
Reaction force	A force of the same size but opposite direction to an action force.
Action-reaction forces	If, A applies an action force to B, B applies a reaction force of same size and opposite direction to A.
Action-reaction vs balanced forces	Similarities: same sizes, opposite directions Differences: balanced forces act on one object, action-reaction act on two different objects

8. Stopping distances	
Stopping distance	The total distance travelled from when a hazard is seen to when you fully stop.
Thinking distance	The distance travelled from when a hazard is seen to when you brake.
Braking distance	The distance travelled from when you brake to when you fully stop.
Calculating stopping distance	Stopping distance = thinking distance + braking distance
Thinking distance and reaction time	Slower reactions = greater thinking distance
Thinking distance increased by…	Higher speed, tiredness, illness, drugs, distractions, old age
Braking distance increased by	Higher speed, poor brakes, poor tyres, wet/icy/gravelly road, downhill, heavier load

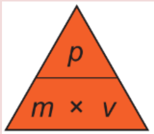
9. Car safety	
Crash danger	Crashes involve large decelerations, creating large forces which can injure you.
How car safety features work	Increase the time a collision takes, reducing deceleration and forces.
Three car safety features	Crumple zones, (stretchy) seat belts, air bags

2. Circular motion (HIGHER AND TRIPLE ONLY)	
Circular motion	Moving in a circle is a type of acceleration because you are changing velocity (your direction changes even if your speed does not).
Centripetal force	A force acting towards the centre of a circle that enables objects to move in a circle.
Sources of centripetal force	Gravity – keeps the Earth orbiting the Sun Tension – lets a bucket swing in circles on a rope Friction – keeps cars turning round a roundabout



4. Inertial mass (HIGHER AND TRIPLE ONLY)	
Inertial mass	The mass calculated by measuring the acceleration produced by force, using the equation m = F / a
The point of inertial mass	Inertial mass is the same as mass measured with a mass balance, but it gives us a way to measure mass where there is no gravity, such as in space.

6. Collisions (HIGHER AND TRIPLE ONLY)	
Action-reaction forces in collisions	E.g. kicking a ball: the foot pushes the ball, the ball pushes back on the foot.

7. Momentum (HIGHER AND TRIPLE ONLY)	
Momentum	The tendency of an object to keep moving.
Calculating momentum	Momentum = mass x velocity p = m x v  Momentum (kg m/s) Mass (kg) velocity (m/s)
Momentum and force calculations	Force = change in momentum / time F = (mv – mu)/t Force (N) Mass (kg) Velocity (m/s) Time (s)
Conservation of momentum	Total momentum before and after a collision is the same.

9. Collision forces (HIGHER AND TRIPLE ONLY)	
Collision forces	Greater momentum change → greater force
Calculating collision forces	Force = change in momentum / time F = (mv – mu)/t Force (N) Mass (kg) Velocity (m/s) Time (s)

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(HIGHER AND TRIPLE ONLY)	
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6. Collisions	
7. Momentum	
9.Collision forces	
10. (TRIPLE ONLY) Braking distance and energy	

10. Braking distance and energy (TRIPLE ONLY)

Work done	The energy transferred by a force acting over a distance is called work done. Measured in joules (J)
Calculating work done	Work done = force x distance moved in the direction of the force  Work done (J) Force (N) distance (m)
Kinetic energy	Energy stored in a moving object Measured in joules (j)
Calculating kinetic energy	kinetic energy = $\frac{1}{2}$ × mass × $(\text{speed})^2$ Kinetic energy (J) Mass (kg) $(\text{Speed})^2$ $(\text{m/s})^2$
Estimating stopping distance using mass, braking force and speed	See worked example below. Remember that work done and energy transferred are the same.

Worked example W3

A 1500 kg car is travelling at 10 m/s. The driver applies a braking force of 10 000 N. How far does the car travel before it comes to a stop?

$$\begin{aligned}\text{kinetic energy} &= \tfrac{1}{2} \times \text{mass} \times \text{velocity}^2 \\ &= \tfrac{1}{2} \times 1500\,\text{kg} \times (10\,\text{m/s})^2 \\ &= 75\,000\,\text{J}\end{aligned}$$

Work done to stop the car is 75 000 J.

$$\begin{aligned}\text{distance} &= \frac{\text{work done}}{\text{force}} \\ &= \frac{75\,000\,\text{J}}{10\,000\,\text{N}} \\ &= 7.5\,\text{m}\end{aligned}$$

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