

Physics 5 Forces – Knowledge Organiser

4.5.1	Forces and their interactions
4.5.1.1 Scalar and vector quantities	Scalar quantities have magnitude (size) only. Vector quantities have magnitude and an associated direction . A vector quantity may be represented by an arrow . The length of the arrow represents the magnitude , and the direction of the arrow the direction of the vector quantity.
4.5.1.2 Contact and non-contact forces	A force is a push or pull that acts on an object due to the interaction with another object. Forces are vector quantities <ul style="list-style-type: none"> • contact forces – the objects are physically touching e.g. friction, air resistance, tension • non-contact forces – the objects are physically separated. e.g. gravitational force, electrostatic force and magnetic force.
4.5.1.3 Gravity	Weight is the force acting on an object due to gravity . The force of gravity close to the Earth is due to the gravitational field around the Earth. The weight of an object depends on the gravitational field strength at the point where the object is. The weight of an object can be calculated using the equation: weight = mass × gravitational field strength $W = m g$ weight, W , in newtons, N, mass, m , in kilograms, kg gravitational field strength, g , in newtons per kilogram, N/kg The weight of an object may be considered to act at a single point referred to as the objects ' centre of mass '. The weight of an object and the mass of an object are directly proportional . Weight is measured using a calibrated spring-balance (a newtonmeter).
4.5.1.4 Resultant forces	The resultant force has the same effect as all the original forces acting together. If forces are balanced the resultant force is zero . (HT only) use accurate scale drawings (vector diagrams) to determine the resultant of two forces, to include both magnitude and direction.
4.5.2	Work done and energy transfer
	A force causes an object to move through a distance work is done on the object. So a force does work on an object when the force causes a displacement (movement) of the object. The work done by a force on an object can be calculated using the equation: work done = force × distance $W = F s$ work done, W , in joules, J force, F , in newtons, N ,distance, s , in metres One joule of work is done when a force of one newton causes a displacement of one metre . 1 joule = 1 newton-metre Work done against the frictional forces acting on an object causes a rise in the temperature of the object.
4.5.3	Forces and elasticity
	Forces are involved in stretching, bending or compressing (squashing) an object <ul style="list-style-type: none"> • to change the shape of a stationary object (by stretching, bending or compressing), more than one force has to be applied • elastic deformation (goes back to original) and inelastic deformation (does not return to original length / shape) The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded force = s pring constant × extension $F = k e$

	<p>force, F, in newtons, N, spring constant, k, in newtons per metre, N/m extension, e, in metres, m</p> <p>This also applies to the compression of an elastic object, where 'e' would be the compression of the object. Force = spring constant X compression</p> <p>A force that stretches (or compresses) a spring does work and elastic potential energy is stored in the spring. Provided the spring is not inelastically deformed, the Work done on the spring and the elastic potential energy stored are equal.</p> <p>Work done in stretching (or compressing) a spring (up to the limit of proportionality) is calculated using the equation:</p> $\text{elastic potential energy} = 0.5 \times \text{spring constant} \times \text{extension}^2 \qquad E_e = 1/2k e^2$ <p>Required practical activity 6: investigate the relationship between force and extension for a spring.</p>
4.5.4	Moments, levers and gears (physics only)
	<p>A force or a system of forces may cause an object to rotate. The turning effect of a force is called the moment of the force. The size of the moment is defined by the equation:</p> $\text{moment of a force} = \text{force} \times \text{distance} \qquad M = F d$ <p>moment of a force, M, in newton-metres, Nm, force, F, in newtons, N, distance, d, is the perpendicular distance from the pivot to the line of action of the force, in metres, m.</p> <p>If an object is balanced, the total clockwise moment about a pivot equals the total anticlockwise moment about that pivot.</p> <p>A simple lever and a simple gear system can both be used to transmit the rotational effects of forces.</p>
4.5.5	Pressure and pressure differences (physics only)
4.5.5.1 Pressure in a fluid 1	<p>A fluid can be either a liquid or a gas. The pressure in fluids causes a force normal (at right angles) to any surface.</p> <p>The pressure at the surface of a fluid can be calculated using the equation:</p> $\text{pressure} = \frac{\text{force normal to a surface}}{\text{area of that surface}} \qquad P = \frac{F}{A}$ <p>pressure, p, in pascals, Pa, force, F, in newtons, N, area, A, in metres squared, m^2</p>
4.5.5.1.2 Pressure in a fluid 2 (higher tier)	<p>The pressure due to a column of liquid can be calculated using the equation:</p> $\text{pressure} = \text{height of the column} \times \text{density of the liquid} \times \text{gravitational field strength}$ $[p = h \rho g]$ <p>pressure, p, in pascals, Pa, height of the column, h, in metres, m, density, ρ, in kilograms per metre cubed, kg/m^3, gravitational field strength, g, in newtons per kilogram, N/kg (In any liquid, pressure at a point increases with the height of the column of liquid above that point and with the density of the liquid.</p> <p>A partially (or totally) submerged object experiences a greater pressure on the bottom surface than on the top surface. This creates a resultant force upwards. This force is called the upthrust.</p>
4.5.5.2 Atmospheric pressure	<p>The atmosphere is a thin layer (relative to the size of the Earth) of air round the Earth. The atmosphere gets less dense with increasing altitude (height). Air molecules colliding with a surface create atmospheric pressure. The number of air molecules (and so the weight of air) above a surface decreases as the height of the surface above ground level increases. So as height increases there is always less air above a surface than there is at a lower height. So atmospheric pressure decreases with an increase in height.</p>
4.5.6	Forces and motion
4.5.6.1.1 distance and displacement	<p>Distance is how far an object moves. Distance does not involve direction. Distance is a scalar quantity. Displacement includes both the distance an object moves, measured in a straight line from the start point to the finish point and the direction of that straight line. Displacement is a vector quantity.</p>

<p>4.5.6.1.2 Speed</p>	<p>Speed does not involve direction. Speed is a scalar quantity. When people walk, run or travel in a car their speed is constantly changing. The speed at which a person can walk, run or cycle depends on many factors including: age, terrain, fitness and distance travelled. walking 1.5 m/s, running 3 m/s, cycling 6 m/s.</p> <p>. The speed of sound and the speed of the wind also vary. A typical value for the speed of sound in air is 330 m/s.</p> <p>For an object moving at constant speed the distance travelled in a specific time can be calculated using the equation:</p> <p><i>distance travelled = speed × time</i> <i>s = v t</i></p> <p>distance, <i>s</i>, in metres, speed, <i>v</i>, in metres per second, m/s, time, <i>t</i>, in seconds, s</p>
<p>4.5.6.1.3 Velocity</p>	<p>The velocity of an object is its speed in a given direction. Velocity is a vector quantity. (HT only) Motion in a circle involves constant speed but changing velocity (because the direction constantly changes).</p>
<p>4.5.6.1.4 The distance-time relationship</p>	<p>If an object moves along a straight line, the distance travelled can be represented by a distance–time graph. The speed of an object can be calculated from the gradient of its distance–time graph.</p> <p>(HT only) If an object is accelerating (getting faster), its speed at any particular time can be determined by drawing a tangent and measuring the gradient of the distance–time graph at that time.</p>
<p>4.5.6.1.5 Acceleration</p>	<p>The average acceleration of an object can be calculated using the equation:</p> <p><i>acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$</i> <i>a = $\frac{\Delta v}{t}$</i></p> <p>acceleration, <i>a</i>, in metres per second squared, m/s², change in velocity, Δv, in metres per second, m/s, time, <i>t</i>, in seconds, s</p> <p>An object that slows down is decelerating.</p> <p>The acceleration of an object can be calculated from the gradient of a velocity–time graph. (HT only) The distance travelled by an object (or displacement of an object) can be calculated from the area under a velocity–time graph e.g. by counting squares.</p> <p>The following equation applies to uniform acceleration:</p> <p><i>final velocity</i>² – <i>initial velocity</i>² = 2 × <i>acceleration</i> × <i>distance</i></p> <p><i>v</i>² – <i>u</i>² = 2 <i>a s</i></p> <p>final velocity, <i>v</i>, in metres per second, m/s, initial velocity, <i>u</i>, in metres per second, m/s, acceleration, <i>a</i>, in metres per second squared, m/s², distance, <i>s</i>, in metres, m</p> <p>Near the Earth’s surface any object falling freely under gravity has an acceleration of about 9.8 m/s². An object falling through a fluid initially accelerates due to the force of gravity. Eventually the resultant force will be zero and the object will move at its terminal velocity.</p> <p>(Physics only) Describe velocity–time graphs for objects that reach terminal velocity e.g. a parachutist</p>
<p>4.5.6.2.1 Newton’s first law</p>	<p>Newtons ‘First Law:</p> <p>If the resultant force acting on an object is zero and:</p> <ul style="list-style-type: none"> • the object is stationary, the object remains stationary • the object is moving, the object continues to move at the same speed and in the same direction. So the object continues to move at the same velocity.

	<p>So, when a vehicle travels at a steady speed the resistive forces balance the driving force. The velocity (speed and/or direction) of an object will only change if a resultant force is acting on the object.</p> <p>(HT only) The tendency of objects to continue in their state of rest/uniform motion is called inertia.</p>
<p>4.5.6.2.2 Newton's second law</p>	<p>Newton's Second Law: The acceleration of an object is proportional to the resultant force acting on the object, and inversely proportional to the mass of the object.</p> <p>As an equation: resultant force = mass × acceleration $F = m a$</p> <p>force, <i>F</i>, in newtons, N, mass, <i>m</i>, in kilograms, kg, acceleration, <i>a</i>, in metres per second squared, m/s²</p> <p>(HT only) inertial mass is a measure of how difficult it is to change the velocity of an object</p> <ul style="list-style-type: none"> • inertial mass is defined as the ratio of force over acceleration. <p>Use the symbol for an approximate value or approximate answer, ~</p> <p>Required practical activity 7: investigate the effect of varying the force on the acceleration of an object of constant mass, and the effect of varying the mass of an object on the acceleration produced by a constant force.</p>
<p>4.5.6.2.3 Newton's third law</p>	<p>Newton's Third Law: Whenever two objects interact, the forces they exert on each other are equal and opposite. Students should be able to apply Newton's Third Law to examples of equilibrium situations.</p>
<p>4.5.6.3.1 Stopping distance</p>	<p>The stopping distance of a vehicle is the sum of the distance the vehicle travels during the driver's reaction time (thinking distance) and the distance it travels under the braking force (braking distance). For a given braking force the greater the speed of the vehicle, the greater the stopping distance.</p> <p>(Physics only) Estimate stopping distances and interpret graphs for stopping distance</p>
<p>4.5.6.3.2 Reaction time</p>	<p>Reaction times vary from person to person. Typical values range from 0.2 s to 0.9 s. A driver's reaction time can be affected by tiredness, drugs and alcohol. Distractions may also affect a driver's ability to react.</p>
<p>4.5.6.3.3 Factors affecting braking distance 1</p>	<p>The braking distance of a vehicle can be affected by adverse road (wet or icy) and weather conditions and poor condition of the vehicle's brakes and tyres.</p> <ul style="list-style-type: none"> • estimate how the distance required for road vehicles to stop in an emergency varies over a range of typical speeds.
<p>4.5.6.3.4 Factors affecting braking distance 2</p>	<p>When a force is applied to the brakes of a vehicle, work done by the friction force between the brakes and the wheel reduces the kinetic energy of the vehicle and the temperature of the brakes increases.</p> <p>The greater the speed of a vehicle the greater the braking force needed to stop the vehicle in a certain distance. The greater the braking force the greater the deceleration of the vehicle. Large decelerations may lead to brakes overheating and/or loss of control.</p>
<p>4.5.7</p>	<p>Momentum (HT only)</p>
<p>4.5.7.1 Momentum, moving objects</p>	<p>Momentum is defined by the equation: momentum = mass × velocity $p = m v$</p> <p>momentum, <i>p</i>, in kilograms metre per second, kg m/s, mass, <i>m</i>, in kilograms, kg, velocity, <i>v</i>, in metres per second, m/s</p>
<p>4.5.7.2 Conservation of momentum</p>	<p>In a closed system, the total momentum before an event is equal to the total momentum after the event. This is called conservation of momentum.</p> <ul style="list-style-type: none"> • (physics only) complete calculations involving an event, such as the collision of two objects.

4.5.7.3
Changes in
momentum
(physics
only)

When a force acts on an object that is moving, or able to move, a change in momentum occurs.

The equations $F = m \times a$ and $a = \frac{v - u}{t}$

combine to give the equation $F = \frac{m \Delta v}{\Delta t}$

where $m\Delta v$ = change in momentum, ie force equals the rate of change of momentum.

Safety features such as: airbags, seat belts, gymnasium crash mats, cycle helmets and cushioned surfaces for playgrounds reduce the rate of change of momentum, therefore reducing the force of impact.