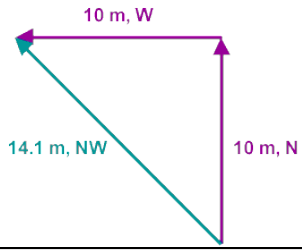
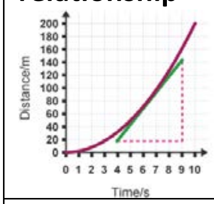
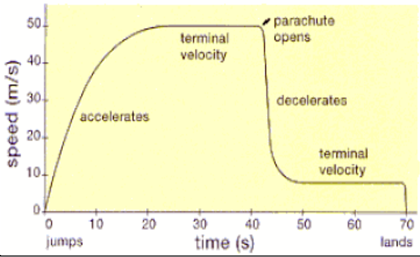
Physics 5 Forces

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 • **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 e.g 
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 • 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 ***f orce = s pring constant* × *extension*** ***F = k e*** force, *F*, in newtons, N ,spring constant, *k*, in newtons per metre, N/m extension, *e*, in metres, m This also applies to the compression of an elastic object, where '*e*' would be the compression of the object. **Force = spring constant X compression** 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**. Work done in stretching (or compressing) a spring (up to the limit of proportionality) is calculated using the equation: ***elastic potential energy* = 0.5 × *s pring constant* × *extension*** ^{2} $E_e = 1/2 k e^2$ **Required practical activity 6:** investigate the relationship between force and extension for a spring.
4.5.4	Moments, levers and gears (physics only)
	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: ***moment o f a f orce = f orce* × *distance*** ***M = F d*** 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. If an **object is balanced,** the total **clockwise moment** about a pivot **equals the total anticlockwise moment** about that pivot. A simple lever and a simple gear system can both be used to transmit the rotational effects of forces.
4.5.5	Pressure and pressure differences (physics only)
4.5.5.1 Pressure in a fluid 1	A **fluid** can be either a **liquid** or a **gas**. The pressure in fluids causes a force normal (at right angles) to any surface. The pressure at the surface of a fluid can be calculated using the equation: **pressure = $\frac{\text{force normal to a surface}}{\text{area of that surface}}$** $P = \frac{F}{A}$ pressure, *p*, in pascals, Pa, force, *F*, in newtons, N, area, *A*, in metres squared, m^2
4.5.5.1.2 Pressure in a fluid 2 (higher tier)	The pressure due to a column of liquid can be calculated using the equation: **pressure = height of the column × density of the liquid × gravitational field strength** **[$p = h \rho g$]**

	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 In a liquid, **pressure** at a point **increases** with the **height** of the column of liquid above that point and with the **density** of the liquid. 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**.
4.5.5.2 Atmospheric pressure	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.
4.5.6	Forces and motion
4.5.6.1	**Describing motion along a line**
4.5.6.1.1 distance and displacement	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.
4.5.6.1.2 Speed	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.** . 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.** For an object moving at constant speed the distance travelled in a specific time can be calculated using the equation: ***distance travelled = s peed × time*** ***s = v t*** distance, *s*, in metres, speed, *v*, in metres per second, m/s, time, *t*, in seconds, s
4.5.6.1.3 Velocity	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).
4.5.6.1.4 The distance-time relationship 	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. (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.
4.5.6.1.5 Acceleration	The **average acceleration** of an object can be **calculated** using the equation: $$acceleration = \frac{change\ in\ velocity}{time\ taken} \qquad a = \frac{\Delta v}{t}$$ acceleration, *a*, in metres per second squared, m/s^2, change in velocity, Δv, in metres per second, m/s, time, *t*, in seconds, s An object that **slows down** is **decelerating.**

	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. The following equation applies to uniform acceleration: ***final velocity* ^{2} *– initial velocity* ^{2} = 2 × *acceleration* × *distance*** $v^2 - u^2 = 2\,a\,s$ final velocity, *v*, in metres per second, m/s, initial velocity, *u*, in metres per second, m/s acceleration, *a*, in metres per second squared, m/s2, distance, *s*, in metres, m **Near the Earth's surface** any object falling freely under **gravity** has an **acceleration** of about **9.8 m/s^2.** 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.** (Physics only) Describe velocity–time graphs for objects that reach terminal velocity e.g. a parachutist 
4.5.6.2	**Forces, accelerations and Newton's laws of motion**
4.5.6.2.1 Newton's first law	**Newtons 'First Law:** If the **resultant force** acting on an object is **zero** and: • 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. So, when a vehicle travels at a **steady speed** the resistive **forces balance** the driving force. The **velocit**y (speed and/or direction) of an object **will only change** if a **resultant force is acting** on the object. (HT only) The tendency of objects to **continue** in their **state of rest** or of **uniform motion** is called **inertia.**
4.5.6.2.2 Newton's second law	**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. As an equation: ***resultant force* = *mass* × *acceleration*** ***F = m a*** force, *F*, in newtons, N, mass, *m*, in kilograms, kg, acceleration, *a*, in metres per second squared, m/s^2 (HT only) **inertial mass** is a measure of **how difficult** it is to **change the velocity** of an object • **inertial mass** is **defined** as the **ratio of force over acceleration**. Use the symbol for an approximate value or approximate answer, ~ **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.

4.5.6.2.3 Newton's third law	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.
4.5.6.3	**Forces and braking**
4.5.6.3.1 Stopping distance	The **stopping distance** of a vehicle is the **sum o**f the distance the vehicle travels during the driver's reaction time (**thinking <u>distance</u>**) and the distance it travels under the braking force (**braking <u>distance</u>**). For a given braking force the **greater the speed** of the vehicle, the **greater the stopping distance**. (Physics only) Estimate stopping distances and interpret graphs for stopping distance
4.5.6.3.2 Reaction time	**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.
4.5.6.3.3 Factors affecting braking distance 1	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**. • estimate how the distance required for road vehicles to stop in an emergency varies over a range of typical speeds.
4.5.6.3.4 Factors affecting braking distance 2	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.** 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.
4.5.7	Momentum (HT only)
4.5.7.1 momentum is a property of moving objects	**Momentum** is defined by the equation: ***momentum = mass × velocity*** ***p = m v*** momentum, *p*, in kilograms metre per second, kg m/s, mass, *m*, in kilograms, kg, velocity, *v*, in metres per second, m/s
4.5.7.2 Conservation of momentum	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.** • (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.