SYLLABUS REFERENCE	RELATED INFORMATION
<u>**Topic 1**</u> <u>**Focus 1**</u> **The Earth has a gravitational field that exerts a force on objects both on it and around it.**	
• **Define weight as the force on an object due to a gravitational field.**	**Weight** is the force applied to an object by a gravitational field. It is defined as: $F = mg$ Where: F – Force (weight) in Newtons m – Mass is kilograms. g – Gravitational field vector (9.8 ms^{-1} on Earth)
• **Explain that a change in gravitational potential energy is related to work done.**	The **gravitational potential energy** (GPE) of an object at a finite distance (*h*) from a mass (*m*) is equal to the work done in moving it to that position. E_P = *mg?h* = Work done Where: m – Mass of object in kilograms. g – Gravitational field vector. ?h – Change in height of the object from the mass in metres.
• **Define gravitational potential energy as the work done to move an object from an object a very large distance away to a point in a gravitational field.**	The **gravitational potential energy** (GPE) of an object is the energy of a mass due to its position within a gravitational field. $E_p = -G\frac{m_1 m_2}{r}$ Due to the inverse square relationship, the GPE will only drop to zero at an infinite distance from the planet. The formula is negative for objects closer than infinity as the further an object is away from a mass, the higher the GPE must be.
• **Perform an investigation and gather information to determine a value for acceleration due to gravity using pendulum motion or computer assisted technology and identify reason for**	<u>**Pendulum Motion Experiment**</u> <u>Aim:</u> To determine an experimental value for the gravitational field vector, g. <u>Method:</u> 1. Set up apparatus. 2. Set string length to 1.20m. 3. The plumb bob was pulled back parallel to the bench through an angle of about 20. It was released and timed to complete 10 oscillations. 4. Repeat step 3, decreasing the string by approximately 0.10m per test. Repeat this for numerous string lengths.

possible variations from the value 9.8 ms^{-2}.

5. Use formula: $g = \frac{4\pi^2 l}{T^2}$ to determine value for g on each test.
6. Graph $4p^2l$ against T. Apply line of best fit and gradient is gravitational field vector.

<u>Sources of Error:</u>

- Human reaction.
- Deviation in swing path.
- String not weightless.
- Measurement errors.

<u>Possible Improvements:</u>

- Use video camera for more accurate time recordings.
- Use video frame-by-frame analysis to account for air-resistance.

- **Gather secondary information to predict the acceleration due to gravity on other planets.**

Formula used is:

$$g = \frac{Gm_{planet}}{r^2}$$

Where:

g – Gravitational field vector on that planet.

m – Mass of planet in kilograms.

r – Radius of planet in metres.

Body	Mass (kg)	Radius (m)	g on Surface (ms^{-2})
Jupiter	1.90E+27	71492000	24.78
Saturn	5.69E+26	60268000	10.44
Neptune	1.03E+26	24764000	11.20
Uranus	8.68E+25	25559000	8.86
Earth	5.98E+24	6378100	9.80
Venus	4.87E+24	6051800	8.86
Mars	6.42E+23	3397000	3.71
Mercury	3.30E+23	2439700	3.70
Granymede	1.48E+23	2631000	1.43
Titan	1.35E+23	2575000	1.36
Callisto	1.08E+23	2400000	1.25
Io	8.92E+22	3500000	0.49
Moon	7.35E+22	1737400	1.62
Europa	4.87E+22	1565000	1.33
Triton	3.17E+22	1350000	1.16
Pluto	1.20E+22	1180000	0.57

- **Analyse information using the expression $F = mg$ to determine the weight force for a body on Earth and for the same body on other planets.**

Using values for g from above table and substitute into the formula:

$F = mg$

80kg mass.

On Earth:

$F = mg$

F = 80 x 9.8

F = 784 N

	On Mars: $F = mg$ F = 80 x 3.7 F = 296 N
<u>Focus 2</u> **Many factors have to be taken into account to achieve a successful rocket launch, maintain a stable orbit and return to Earth.**	
• **Describe the trajectory of an object undergoing projectile motion within the Earth's gravitational field in terms of horizontal and vertical components.**	The trajectory of a projectile is the path that it follows during its flight. Any object propelled into the air near to the Earth's surface will follow a **parabolic path**. **Properties of a projectile:** • The horizontal (*x*) component of its velocity will remain constant (neglecting air resistance). • The vertical component (*y*) of its velocity will experience a force of acceleration due to gravity of 9.8 ms^{-2}. When applying this to formulas, this acceleration is given a negative value.
• **Describe Galileo's analysis of projectile motion.**	**Galileo's Analysis:** • Galileo proposed that all projectiles took a **parabolic path**. • He also proposed that a stone and a feather would reach the ground at the same time if they were dropped from the same height provided there was no air resistance. • He also said that horizontal and vertical components of projectile motion occurred independent of each other yet simultaneously.
• **Explain the concept of escape velocity in terms of the *gravitational constant & mass and radius of the planet*.**	The **escape velocity** of a planet is the initial velocity required by a projectile to rise vertically and just escape the gravitational field of a planet. It is calculated using the following equation: $v = \sqrt{\frac{2Gm_p}{r}}$ As the **gravitational constant**, *G*, is the same everywhere, the escape velocity of a planet is only dependant on the **mass and radius** of a planet. • As the **mass** of a planet increases, so does the **escape velocity**. • As the **radius** of a planet **increases**, the **escape velocity decreases**.
• **Outline Newton's concept of escape**	Newton proposed that if an object was projected fast enough it should be possible for it to achieve an **orbit** around Earth.

velocity.	• If this velocity (**escape velocity**) is achieved, the projectile goes into a **circular orbit** around Earth. • If this velocity is exceeded, the projectile will fall into an **elliptical orbit** around Earth. If it is exceeded still it will follow a **parabolic** or **hyperbolic path** away from Earth. • If this velocity **is not** reached, the projectile will fall back to earth along a **parabolic** path.
• **Identify why the term 'g' forces is used to explain the forces acting on an astronaut during launch.**	The term **'g' force** is used to describe an objects **apparent weight** as a proportion of its **true weight**. **True weight** is the force applied by gravity on an object that is **not accelerating**. **Apparent weight** is what an object experiences when an external force (**acceleration**) acts upon it. The following formulas calculate 'g' forces: $g\ force = \frac{apparent\ weight}{true\ weight}$ $g\ force = \frac{\mathbf{g} + a}{9.8}$
• **Discuss the effect of the Earth's orbital motion and its rotational motion on the launch of a rocket.**	A rocket can achieve its **greatest velocity** with minimal fuel if it is launched to the East from the equator. This is because the **Earth spins from West to East**, so a rocket launched to the East will receive a speed boost. Since the **fastest surface speed** is obtained at the **equator**, this is where the biggest boost will be obtained from. • If the rocket is launched against the rotation of the Earth it will transfer to an orbital path **nearer to the sun** than that of Earth as its overall velocity will be less than Earth's. • If the rocket launches with the rotation of the Earth, the rocket's boost means that it will obtain a **larger orbit** than that of Earth.
• **Analyse the changing acceleration of a rocket during launch in terms of the: *law of conservation of momentum* & the *forces experience by astronauts*.**	The movement of a rocket can be split up into two equal and opposite forces. • The force of the rocket propelling forwards • The force of the gases propelling backwards. The **momentum of the gases must equal the momentum of the rocket**. $p_{rocket} = p_{gases}$ $\mathbf{m}v = \mathbf{m}v$ Since there is no net change in momentum in the system, the **Law of Conservation of Momentum** is obeyed. **Forces Acting on an astronaut:** There are two main forces acting on an astronaut: • The thrust of the rocket. • The effect of gravity pulling down. (mg) **Thrust** is the force delivered to a rocket by its engines.
• **Analyse the forces involved in**	**Uniform circular motion** is circular motion with a uniform orbital speed.

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uniform circular motion for a range of objects, including satellites orbiting the Earth.

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The **centripetal force** is the force that acts to maintain circular motion and is directed towards the centre of the circle. The centripetal force is calculated by:

$$F_c = \frac{mv^2}{r}$$

<table>
<tr><th>Circular Motion</th><th>Centripetal Force (ma)</th></tr>
<tr><td>Satellite orbiting Earth</td><td>Earth's gravitational pull</td></tr>
<tr><td>Car driving around corner</td><td>Friction between tyres and the road</td></tr>
<tr><td>Rock whirled round on a string</td><td>Tension on string.</td></tr>
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- **Compare qualitatively low Earth and geostationary orbits.**

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A **low Earth orbit** is an orbit higher than 250km and lower than 1000km. This puts them high enough to avoid atmospheric drag yet low enough to avoid the Van Allen radiation belts.

- Have faster orbital velocity (27 900 kmh^{-1}) than geostationary satellites.
- Used to survey the surface.
- Take about 90 minutes to complete an orbit.
- Their orbits are at the lower limits of the Van Allen radiation belts.

A **geostationary orbit** is an orbit at an altitude at which the period of the orbit precisely matches that of the Earth. This corresponds to an altitude of approximately 35 800km.

- They orbit at the equator
- The satellites stay over the one point on the Earth.
- These satellites are used for weather and communication satellites.
- They orbit at the upper limits of the Van Allen radiation belts. Therefore, geostationary orbits do have issues with radio waves being interfered with by the Van Allen radiation belts during communication with ground based stations.

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- **Define the term orbital velocity and the quantitative and qualitative relationship between orbital velocity, the gravitational constant, mass of the central body, mass of the satellite and the radius of the orbit**

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Orbital velocity is the instantaneous speed in the direction of a tangent drawn to a point on an orbital path.

Kepler's Law of Periods:

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

The orbital velocity of an object is equal to:

$$\text{Orbital Velocity} = \frac{\text{Circumference of the circle}}{\text{Period } T}$$

$$v = \frac{2\pi r}{T}$$

If this expression for orbital velocity is substituted into Kepler's Law of Periods, then a formula for orbital velocity

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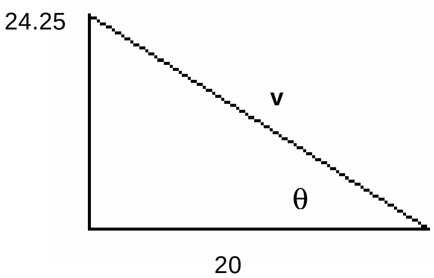
using Kepler's Law of Periods.	for a satellite is: $v = \sqrt{\frac{GM}{r}}$ The **orbital velocity** of a satellite depends upon: • The mass of the planet being orbited • The radius of the orbit. (Usually radius of planet + altitude)
• **Discuss issues associated with safe re-entry into the Earth's atmosphere and landing on the Earth's surface.**	**Issues:** • As a spacecraft enters the Earth's atmosphere an immense amount of heat is produced. This is due to the extremely high velocity it travels and its **collisions with particles** in the atmosphere. If the heat is not dissipated the craft may burn up. The heat shields, therefore, spread the heat evenly. • As the heat builds up around the craft, particles in the air are ionised, producing a phenomenon called **ionisation blackout**. These particles deflect any radio waves and therefore make the craft un-contactable. • The **deceleration** during re-entry can cause huge 'g' forces, which can cause blood to rush to the brain. This can be minimised by reclining the astronaut so these forces are applied perpendicular to the astronaut's long axis. • A human body can only withstand a maximum safe 'g' force of around 8g's. A 'g' force of around 20g's will kill an astronaut. • The spacecraft must **touch down softly**. This is achieved by using parachutes or landing in the ocean.
• **Identify that there is an optimum angle for safe re-entry for a manned spacecraft into the Earth's atmosphere and the consequences of failing to achieve this angle.**	The angle of **re-entry** must be between **5.2° and 7.2°**. • If the angle is too shallow the spacecraft will bounce off back into space. • If the angle is too steep, the spacecraft will burn up due to excessive drag.
• **Solve problems and analyse information to calculate the actual velocity of a projectile from its horizontal and vertical**	**Formula Deconstruction:** • v is the velocity in **ms^{-1}**. It can be for either the x-component or y-component. • u is the initial velocity in **ms^{-1}**. It can also be fore either the x-component or y-component. • a is the acceleration in **ms^{-2}**. Whilst it can represent either axis in projectile motion it only represents gravity in

components using: o $v_x^2 = u_x^2$ o $v = u + at$ o $v_y^2 = u_y^2 + 2a_y?y$ o $?x = u_xt$ o $?y = u_yt + ½a_yt^2$	the y-axis. • *?y* is the displacement in the y-axis in **metres**. • *?x* is the displacement in the x-axis in **metres**. • *t* is the unit of time in seconds **(s)**. **Sample Question:** A rock is projected horizontally from a cliff 30m above the ground at $20ms^{-1}$. Find: a) The time the rock was in the air b) The horizontal distance travelled by the rock from the base of the cliff. c) The horizontal speed of the rock just before it hit the ground. d) The vertical speed of the rock just before it hit the ground. e) The total velocity just before the rock hit the ground. **Solutions:** Part a) $?y = u_yt + ½a_yt^2$ $-30 = 0 \times t + ½ \times -9.8 \times t^2$ $t = \sqrt{\frac{-30}{-4.9}}$ t = 2.47 secs Part b) $?x = u_xt$ x = 20 x 2.47 x = 49.4 m Part c) Horizontal velocity does not change. (neglecting air resistance) Therefore, $v_x = 20\ ms^{-1}$ Part d) $v_y^2 = u_y^2 + 2a_y?y$ $v^2 = 0 + 2 \times -9.8 \times -30$ $v = \sqrt{588}$ $v = 24.25\ ms^{-1}$. Part e)  $v = \sqrt{20^2 + 24.25^2}$ $v = 31.43\ ms^{-1}$. $\theta = \tan^{-1}\left(\frac{24.25}{20}\right)$ $\theta = 50^\circ 29'$ Therefore, the velocity is $31.43\ ms^{-1}$ at 50°29' to the ground.
• **Perform a first hand**	**Practical Investigation:** <u>Aim:</u>

investigation, gather information and analyse data to calculate the initial and final velocity, maximum height reached, range and time of flight of a projectile for a range of situations by using simulations, data loggers and computer analysis.	To investigate the path of a projectile. Method: 1. Set up projectile launcher on a variety of different angles and fired a projectile at the same velocity from differing angles. The time of flight was recorded. 2. Where the projectiles landed were marked and recorded. 3. The horizontal displacement and time was then substituted into the projectile motion formulas and results obtained for maximum height, etc. Conclusion The path taken by the projectiles was in a parabolic path.
• **Identify data sources, gather, analyse and present information on the contribution of one of the following to the development of space exploration: Tsiolkovsky, Oberth, Goddard, Esnault-Peltrie, O'Neill or Von Braun.**	**Wernher Von Braun** Von Braun was one of the world's first and foremost **rocket engineers** and a leading authority on space travel. His will to expand man's knowledge through the exploration of space led to the development of the Explorer satellites, the Jupiter and Jupiter-C rockets, Pershing, the Redstone rocket, Saturn rockets, and Skylab, the world's first space station. Additionally, his determination to "go where no man has gone before" led to mankind setting foot on the moon. He built the **A-4 (V-2) rockets** for the Germans to attack London but did not agree with the war so surrendered to the Americans. He and his rocket parts were taken to America. He worked on the **first satellite ever sent into space** and is regarded as the **father of the United States space program**.
• **Solve problems and analyse information to calculate the centripetal force acting on a satellite undergoing uniform circular motion about the Earth using** $F = \frac{mv^2}{r}$.	$F = \frac{mv^2}{r}$ • F is the centripetal force in **Newtons (N)**. • m is the mass of the object or satellite in **kilograms (kg)**. • v is the instantaneous orbital velocity of the object in **ms^{-1}** • r is the radius of the circular motion in **metres (m)**. **Sample Problem:** A car of mass 1450kg is driving around a bend of radius 70m. Determine the centripetal force is the car is travelling at $70km\ h^{-1}$. **Solution:** Firstly, $70km\ h^{-1} = 70 / 3.6 = 19.4\ ms^{-1}$. Then: $F = \frac{mv^2}{r}$

	$F = \frac{1450 \times 19.4^2}{70}$ F = 7800 N
• **Solve problems and analyse information using** $\frac{\boldsymbol{r}^3}{\boldsymbol{T}^2} = \frac{\boldsymbol{GM}}{4p^2}$ **.**	$\frac{\boldsymbol{r}^3}{\boldsymbol{T}^2} = \frac{\boldsymbol{GM}}{4p^2}$ • *r* is the radius of the orbit of any given satellite in **metres**. • *T* is the period of the satellite's orbit in **seconds**. • *G* is the universal gravitational constant = **6.676 x 10^{-11} N m^2 kg^{-2}** • *M* is the mass of the central body in **kilograms (kg)**. **Sample Problem:** Calculate the period of a satellite orbiting 400km above the Earth. The Earth's radius is 6.38 x 10^6m and the Earth's mass is 5.97 x 10^{24} kg. **Solution:** $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ $\frac{6.38 \times 10^6 + 400 \times 10^3}{T^2} = \frac{(6.67 \times 10^{-11}) \times (5.97 \times 10^{24})}{4\pi^2}$ T = 5560 seconds = 92.7 minutes.
<u>Focus 3</u> **The solar system is held together by gravity.**	
• **Describe a gravitational field in the region surrounding a massive object in terms of its effects on other masses in it.**	A **gravitational field** is a field within which any mass will experience a **gravitational force of attraction** towards the central body. The field has both strength and direction. The central body exerts a **force of attraction**, which becomes the **centripetal force** that allows objects to orbit around it.
• **Define Newton's Law of Universal Gravitation:** $\boldsymbol{F = \frac{Gm_1m_2}{d^2}}$	**Newton's Law of Universal gravitation** states that the gravitational attraction of two planets in directly proportional to the product of their masses and is inversely proportional to the square of the distance between them. The formula for this is: $F = \frac{Gm_1m_2}{d^2}$
• **Discuss the importance of Newton's Law of Universal Gravitation in understanding**	We know that the **force of attraction** between a satellite and a planet is the same value as the **centripetal force** in **circular motion**. Therefore we can equate the two formulas to produce a formula for the velocity of a satellite.

and calculating the motion of satellites.	$\frac{Gm_E m_S}{r^2} = \frac{m_S v^2}{r}$ $v = \sqrt{\frac{Gm_E}{r}}$ As we also know, Kepler had stated in his **law of periods** that $\frac{\mathbf{r^3}}{T^2} = \mathbf{k}$ but was not able to determine a value for k. The expression relating period to **orbital velocity** was then substituted and re-arranged. $\frac{2\pi r}{T} = \sqrt{\frac{Gm}{r}}$ $\frac{r^3}{T^2} = \frac{Gm}{4\pi^2} = k$
• **Identify that a slingshot effect is provided by planets for space probes.**	The **slingshot effect**, or **planetary swing-by** or **gravity-assist manoeuvre**, is a strategy used with space probes to achieve a change in velocity with little expenditure of fuel. As the probe approaches the planet it is swung around the planet by gravity. The net effect is that the planet loses kinetic energy as the probe gains some.
• **Present information and use available evidence to discuss the factors affecting the strength of the gravitational force.**	**Factors affecting the strength of the gravitational force**: • The **force** is **proportional** to the **product of the two masses**. • The **force** is **inversely proportional** to the **distance between the two masses**. **Mathematically:** $F = \frac{Gm_1 m_2}{d^2}$
• **Solve problems and analyse information using** $\mathbf{F = \frac{Gm_1 m_2}{d^2}}$ **.**	Example Problem: Given the following data, determine the magnitude of the gravitational attraction between the earth and the moon. Mass of the Earth: 5.97×10^{24} kg Mass of the Moon: 7.35×10^{22} kg Earth-Moon Distance: 3.84×10^{8} m Solution: $F = \frac{Gm_1 m_2}{d^2}$ $F = \frac{(6.67 \times 10^{-11})(5.97 \times 10^{24})(7.35 \times 10^{22})}{(3.84 \times 10^{8})^2}$ $F = 1.98 \times 10^{20}\ N$
Focus 4 **Current and emerging**	

understanding about time and space has been dependent upon earlier models of the transmission of light.	
• **Outline the features of the aether model for the transmission of light.**	The **aether** was a hypothesised medium for light and other **electromagnetic waves** to **propagate**. It was based on the belief that all **transverse waves** required a medium in which to propagate. This was later disproved. The **aether** was hypothesised as: • Invisible • Luminiferous • Can permeate all matter • Has great elasticity • Was completely permeable to material objects.
• **Describe and evaluate the Michelson-Morley attempt to measure the relative velocity of the earth through the aether.**	The **Michelson-Morley experiment** was designed to see if the **aether** did exist. The aether supposedly existed in space, and the earth spins at about 30 km h^{-1}. Therefore, if the aether did exist, the earth should experience an aether wind just like a swimmer swimming across a current and light should be slowed down when travelling into the 'wind.' A light ray was shone into the half-silvered mirror. Ray 1 heads on into the aether, then reflects off Mirror M_1, reflects off the central mirror and finished at T. Ray 2 is reflected from the central mirror towards mirror M_2. It is reflected off mirror M_2, before returning to T. An **inference pattern** was shown for both rays when they reached the **inferometer** at T. The whole apparatus was rotated by 90° with the idea being that the aether wind would cause a change in the **inference patterns**. The experiment was also repeated over various stages of the year, during different seasons. The result was that the inference patterns were the same for each attempt and the experiment was given a **null** result.
• **Discuss the role of the Michelson-Morley experiment in making determinations about competing theories.**	The **Michelson-Morley experiment** made determinations against the aether model. However, it was not until **Einstein** explained the **null result** that the aether model was disproven. Einstein stated that the null result meant two things: • The aether **does not** exist • The **speed of light** is the same for all observers.
• **Outline the nature of inertial frames**	An **inertial frame of reference** is a **non-accelerated** environment. This includes objects at rest or travelling with

of reference.	uniform velocity.
• **Discuss the principle of relativity.**	Galilean relativity states that the same laws of physics apply in stationary frames of reference and frames of reference with a constant velocity. Newtonian relativity states that in an inertial frame of reference you cannot tell whether it is moving or stationary. Einstein's special relativity had two postulates: • The laws of physics are the same in all inertial frames of reference. • The speed of light is constant and is independent of the velocity of the source or observer.
• **Describe the significance of Einstein's assumption of the consistency of the speed of light.**	As a result of Einstein's theory that the speed of light remained constant the null result achieved during the Michelson-Morley experiment could be explained. The null result meant that the aether didn't exist. Einstein then theorised that nothing can travel faster than the speed of light and it also allowed him to propose his theories of time dilation, length contraction and mass dilation.
• **Identify that if *c* is constant then space and time become relative.**	In Newtonian relativity, space is relative to the observer but time is constant. In Einstein's theory of special relativity space and time also become relative. This means that the time taken for an event is relative to the nature of the observer. This is the concept of the space-time continuum. The formula for velocity is: $v = \frac{d}{t}$ Therefore, if v becomes a constant, c, then d and t all of a sudden must become relative.
• **Discuss the concept that length standards are defined in terms of time in contrast to the original metre standard.**	Up until recently the metre was defined as the distance between two marks on a platinum-iridium bar in Paris. However, the definition of a second and the speed of light have become more accurate, so therefore so must the definition of a metre. The definition of a metre is the distance light travels in $\frac{1}{c}$ seconds. As Einstein stated, the value for c is constant regardless of the frame of reference and therefore the measurement of a metre is unaffected by time dilation or length contraction.

• **Explain qualitatively and quantitatively the consequences of special relativity in relation to:** o **The relativity of simultaneity** o **The equivalence between mass and energy.** o **Length contraction** o **Time dilation.** o **Mass dilation.**	**Relativity of Simultaneity:** A person standing an equal distance from two events that occur at the same time will judge these events to be simultaneous. Another observer, standing closer to one event or the other may not judge these events to be simultaneous. This is because it takes longer for the light from the event to get to an observer standing further away. Therefore, simultaneity is dependent upon the frame of reference. **Equivalence of Mass & Energy:** The rest mass of an object is equal to a certain quantity of energy. In nuclear reactions this mass can be converted to energy, and conversely, energy can be converted to mass. This relationship is known as the Law of Conservation of Mass-Energy in special relativity and is represented as: $E = mc^2$ **Length Contraction:** The length of an object at rest is known as its proper length (L_o), and this length is contracted (L_v) when an object is moving. This is represented as: $L_v = L_O\sqrt{1 - \left(\frac{v^2}{c^2}\right)}$ **Time dilation:** The time for an event to occur as observed by an observer in the same frame of reference as the event is called t_o. However, observers in different frames of reference will judge this event to take longer (t_v). This is expressed by: $t_v = \frac{t_O}{\sqrt{1 - \frac{v^2}{c^2}}}$ **Mass Dilation:** As the velocity of an object increases, so does its mass. Its rest mass is known as m_o, whilst its moving mass is known as m_v and can be expressed as: $m_v = \frac{m_O}{\sqrt{1 - \frac{v^2}{c^2}}}$
• **Discuss the implications of mass increase, time dilation and length contraction**	**Mass increase** means that if a particle was to be accelerated to the speed of light it would have infinite mass, so to accelerate it to this point would require infinite energy. Therefore an object, or spacecraft, cannot be accelerated to the speed of light.

for space travel.	As a result of **time dilation**, by travelling close to the speed of light, the trip, as observed by someone from the outside, appears longer. As a result of **length contraction**, the spacecraft would appear shorter.
• **Perform an investigation and gather first-hand or secondary data to model the Michelson-Morley experiment.**	<u>Experiment:</u> <u>Aim:</u> To model the Michelson-Morley experiment. <u>Model:</u> The logic behind this is that two swimmers represent each of the light beams sent off during the actual experiment. If the **aether** did exist, then one swimmer would be swimming into the current, another across it.
• **Perform an investigation to help distinguish between inertial and non-inertial frames of reference.**	<u>Experiment:</u> <u>Aim:</u> To use an accelerometer to distinguish between inertial and non-inertial frames of reference. <u>Method:</u> Set up apparatus. Record the readings on the accelerometer when the mass is let go. <u>Conclusion:</u> When the trolley speeds up, the accelerometer records a positive value. When the trolley slows down, the accelerometer records a negative value.
• **Analyse and interpret some of Einstein's thought experiments involving mirrors and trains and discuss the relationship between thought and relativity.**	Experiments at near **light-speed velocities** are impossible currently so **Einstein**'s only option of testing his theories was a **thought experiment**. *Imagine you are sitting in a train facing forwards. The train is moving at the speed of light. You hold up a mirror in front of you. Will you be able to see your reflection?* The answer is **yes** because **Einstein** decided that the **principle of relativity** would not be violated. This meant that the reflection is leaving the mirror at 3 x 10^8 ms^{-1}. However, this would mean that an observer on the train platform would see the event occurring at twice its normal speed. **Einstein** believed this to be impossible and therefore stated that **time** must be different for each observer.
• **Analyse information to discuss the relationship between theory and the evidence supporting it, using Einstein's predictions based on relativity that**	Any theory, no matter how logical, cannot stand with experimental evidence backing it up. This is true for many of **Einstein**'s theories; however, it wasn't for many years after that they were eventually proven. Facts that have since been discovered that support **Einstein**'s theories: • Two extremely accurate atomic clocks were synchronised. One remained on the Earth's surface while the other was flown around the world in jet aeroplanes. When the second clock returned there was found to be a

were made many years before evidence was available to support it.	slight difference between the two which proved time dilation had occurred. • Many muons can be detected at sea level, but the trip from the upper atmosphere to the surface would take longer than the muon's lifetime at the speed it is travelling. This also suggests time dilation and length contraction have occurred. • The fact that energy can be produced from fission reactors verifies the energy-mass equivalence.
• **Solve problems and analyse information using:** $E = mc^2$ $l_v = l_o\sqrt{1-\left(\frac{v^2}{c^2}\right)}$ $t_v = \frac{t_o}{\sqrt{1-\frac{v^2}{c^2}}}$ $m_v = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$	Carefully substitute given values into these equations and do the appropriate calculations.