9.2 Space

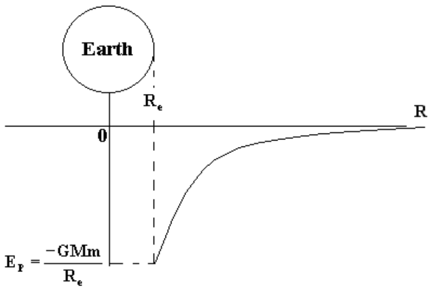
Contextual Outline

Scientists have drawn on advances in areas such as aeronautics, material science, robotics, electronics, medicine and energy production to develop viable spacecraft. Perhaps the most dangerous parts of any space mission are the launch, re-entry and landing. A huge force is required to propel the rocket a sufficient distance from the Earth so that it is able to either escape the Earth's gravitational pull or maintain an orbit. Following a successful mission, re-entry through the Earth's atmosphere provides further challenges to scientists if astronauts are to return to Earth safely.

Rapid advances in technologies over the past fifty years have allowed the exploration of not only the Moon, but the Solar System and, to an increasing extent, the Universe. Space exploration is becoming more viable. Information from research undertaken in space programs has impacted on society through the development of devices such as personal computers, advanced medical equipment and communication satellites, and has enabled the accurate mapping of natural resources. Space research and exploration increases our understanding of the Earth's own environment, the Solar System and the Universe.

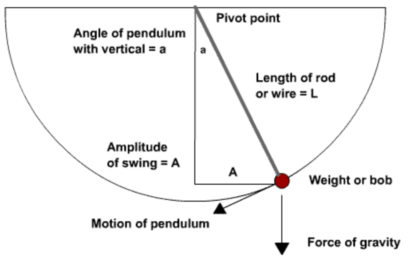
This module increases students' understanding of the history, nature and practice of physics and the implications of physics for society and the environment.

1. **Earth has a gravitational field that exerts a force on objects both on it and around it**	
Students learn to:	*Notes:*
▪ define weight as the force on an object due to a gravitational field	▪ **Mass**: how heavy an object is. It remains constant where ever you go. ▪ **Weight**: The force of gravity acting upon an object. $W = mg$ $W = \text{Weight (N)}$ $m = \text{Mass (kg)}$ $g = \text{Acceleration due to gravity } (m/s^2)$ (Vector Quantity)
▪ explain that a change in gravitational potential energy is related to work done	▪ **Gravitational Potential Energy**: Stored energy of an object due to its position in a gravitational field. $GPE = mgh \text{ (On Earth)}$ $E_p = -\frac{GMm}{r}$ $G = \text{Gravitational Constant } (6.67 \times 10^{-11})$ $M = \text{Mass of big object (kg)}$ $m = \text{Mass of little object (kg)}$ $r = \text{radius of M (m)}$ ▪ **Work**: The amount of energy that is required to move an object. Hence, "work is done" to an object within a gravitational field in order to move it. $\Delta GPE = W$ $\Delta GPE = \text{change in GPE } [GPE_f - GPE_i]$ $W = \text{Work (J)}$ $W = GPE_f - GPE_i = -\frac{GMm}{r_f} - \left(-\frac{GMm}{r_i}\right)$ $= GMm\left(\frac{1}{r_i} - \frac{1}{r_f}\right)$ ▪ Increase in GPE equals decrease in KE [Law of conversation of Energy] $\uparrow GPE = \downarrow KE$ ▪ So, ↑ GPE means its moving away from the gravitated object. [↑ height] $\therefore \text{ at max GPE the height} = \infty$

▪ define gravitational potential energy as the work done to move an object from a very large distance away to a point in a gravitational field $$E_p = -G\frac{m_1 m_2}{r}$$  	▪ Since space is infinitely large, we take $r = \infty$ as a reference point. (Makes it easier to calculate work) $$W = GMm\left(\frac{1}{r_i} - \frac{1}{r_f}\right)$$ Since we start at $r = \infty, r_i = \infty$ $$W = GMm\left(\frac{1}{\infty} - \frac{1}{r_f}\right)$$ $$= GMm\left(0 - \frac{1}{r_f}\right)$$ $$E_p = -\frac{GMm}{r_f}$$ Also came be derived from: $$E_p = -\frac{GMm}{r}$$ $$\int_{\infty}^{r} \frac{GMm}{r^2}$$ $$GMm\left(\frac{-1}{r}\right) \text{ at r and } \infty$$ $$GMm\left(\frac{-1}{\infty} - \frac{-1}{r}\right)$$ $$E_p = -\frac{GMm}{r}$$ ▪ Thus, taking a reference at $r = \infty$, our GPE = 0. When at max height and GPE is 0, anything within the gravitational field will be negative.

Students:	
▪ perform an investigation and gather information to determine a value for acceleration due to gravity using pendulum motion or computer-assisted technology and	**<u>Determine Gravity Via Pendulum Experiment</u>** ▪ **Aim:** With the use of a pendulum, determine ion due to gravity, through the time it takes for 10 oscillations. ▪ **Equipments:** String, Ball, Pendulum, Protractor ▪ **Method:** With the string tied to the ball, position the string hanging and with the protector measure 10 degrees to the vertical. Let go of the ball that that position and time the 10 oscillations swing. Do this for 20 degrees, 30 degrees. ▪ Relation between the period (T), length (l) and the acceleration due to gravity (g) is measure via equation:

identify reason for possible variations from the value 9.8 ms^{-2}



$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$T = \text{Period (s)}$$
$$l = \text{Legnth (m)}$$
$$g = \text{acceleration due to gravity (m/s)}$$
$$\text{Rearraging for calculations of gravity}$$
$$g = \frac{4\pi^2 l}{T^2}$$
$$\text{When graphing these result as}$$
$$y = mx + b$$
$$\text{Were the gradient m should} = \frac{4\pi^2}{g}$$

With this we should be able to calculate **g** to be around **9.8**.

- **Discussion: Factors affecting the result:**
  Position due to Earth: Altitude wise, if you're positioned **higher then ground level**, it would **increase**, and vice versa. **Longitude wise**, if you are **closer to pole** rather than the **equator** then your gravity will **change [Earth is not spherical].**
  Density: The **atmosphere and density** on the location will affect the gravity.

- gather secondary information to predict the value of acceleration due to gravity on other planets

- Accelerations due to gravity of other planets can be derived from **Newton's Law of Gravitation / Newton's Second Law**.

$$F_g = F_W$$
$$\frac{GMm}{r^2} = mg$$
$$g = \frac{GM}{r^2}$$

Calculation made within the **Solar System.**

Planet	Equation	g
Earth	$\frac{(6.67 \times 10^{-11})(6 \times 10^{24})}{(6380000)^2}$	9.80
Moon	$\frac{(6.67 \times 10^{-11})(7.347 \times 10^{22})}{(1737000)^2}$	1.62

- analyse information using the

$$F = mg$$

expression:

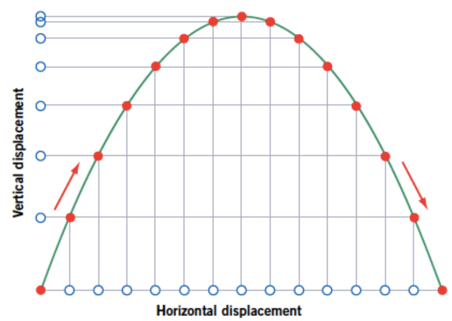
$$F = mg$$

to determine the weight force for a body on Earth and for the same body on other planets

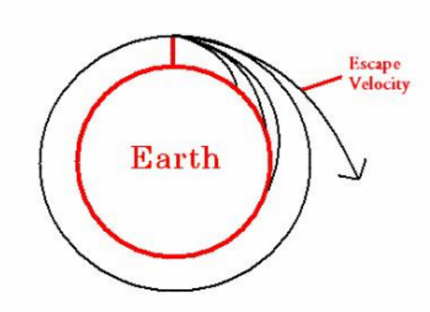
- This equation refers to the force that an object will experience under the influence of gravity. The force will depend on the amount of gravity.
  Calculation made with a **60 kg** mass.

Planet	Equation	N
Mercury	(60)3.68	220.8
Venus	(60)8.87	532.2
Earth	(60)9.80	588
Moon	(60)1.62	97.2

2. Many factors have to be taken into account to achieve a successful rocket launch, maintain a stable orbit and return to Earth

Students learn to:	*Notes:*
▪ describe the trajectory of an object undergoing projectile motion within the Earth's gravitational field in terms of horizontal and vertical components	▪ Objects that are **thrown, launched, dropped** with follow a trajectory path of an "upside down parabola". ▪ Follows a symmetrical parabola when neglecting air resistance. ▪ Galileo stated that the horizontal and vertical components are independent. – Horizontal ➔ Constant velocity [Thrust force or any force that makes the object above the surface]. – Vertical ➔ Always changing [acceleration due to gravity or the gravitational force acting]. – These two components are **superimposed** to create the motion of projectile. 
▪ describe Galileo's analysis of projectile motion	▪ Galileo postulated that all mass whether **big or small** will fall at the same rate due to gravity. DUE to the independence of components AND no air resistance ▪ All objects are subject to only to the acceleration of gravity. ▪ Natural shapes of the trajectory were a concave down parabola. ▪ **Galileo's Experiment:** – Trying to prove this, there was one flaw ➔ air resistance. – Prevented ➔ Rolling balls down highly polished incline. This reduced air resistance/ slowed down motion for more accurate and

	reliable calculations. – Discovered that when these balls rolled and freefall; it curved in a parabolic trajectory.
▪ explain the concept of escape velocity in terms of the: – gravitational constant – mass and radius of the planet	▪ **Escape Velocity**: The minimum velocity that an object must attain to escape the gravitational attraction and launch into infinity. ▪ In order to perform escape velocity, the object must move greater than its GPE. Thus, KE must be greater than or equal to GPE. (Law of energy conservation). $$\mathrm{KE} + \mathrm{GPE} = 0$$ $$\frac{1}{2}\mathrm{mv}^2 = \frac{\mathrm{GMm}}{\mathrm{r}}$$ $$\mathrm{v}^2 = \frac{2\mathrm{GM}}{\mathrm{r}}$$ $$\mathrm{v} = \sqrt{\frac{2\mathrm{GM}}{\mathrm{r}}}$$ $$\mathrm{v} = \text{velocity } (\mathrm{m/s^2})$$ $$\mathrm{G} = \text{Gravitational constant } (6.67 \times 10^{-11})$$ $$\mathrm{M} = \text{Mass of big object (kg)}$$ $$\mathrm{r} = \text{Radius (m)}$$ – gravitational constant $$\mathrm{v} \propto \mathrm{G}$$ – mass and radius of the planet $$\mathrm{v} \propto \mathrm{m} \text{ and } \mathrm{v} \propto {}^{1}\!/_{\mathrm{r}}$$

▪ outline Newton's concept of escape velocity 	▪ Newton's stated the harder an object to launched, the faster and higher it goes. If it achieves escape velocity then it will orbit Earth. ▪ **Newton's Through Experiment:** – Scenario: **A cannonball placed on top of a very tall mountain.** Launched using the horizontal velocity. – It the launch velocity is **lower than escape velocity**, it will **follow a parabolic shape and fall to Earth.** The **faster the velocity, the further it would travel (increases in range)** – If the launch velocity has the **sufficient escape velocity**, it will **travel around Earth; because at the same rate of falling, the Earth's surface curves away from its projectile.** It's in orbit **(orbital motion, circular motion)** – If the launch velocity **exceeds escape velocity**, the **object would escape the gravitational attraction and head towards infinity.** $$v = \sqrt{\frac{2GM}{r}}$$
▪ identify why the term 'g forces' is used to explain the forces acting on an astronaut during launch	▪ **G-force:** The ratio of an individual's apparent weight over their true weight. $$\text{G} - \text{force} = \frac{\text{Apparent Weight}}{\text{True Weight}}$$ $$\text{Apparent Weight} = \text{The sensation weight an individual feels.}$$ $$(\sum \text{Sum of forces resisting on True Weight})$$ $$\text{True Weight} = \text{Normal Weight (mg)}$$ ▪ **Expressed in multiple of g.**
▪ discuss the effect of the Earth's orbital motion and its rotational motion on the launch of a rocket	▪ **Economical Launching:** Ways that benefits the rockets from using too much fuel. ▪ The Earth rotates on its own axis and around the sun. → Rotates east. Two motions: **Earth rotational motion + orbital motion around the Sun == high velocity boost relative to the Sun.** ▪ To **maximise fuel efficiency**, rockets are launched at the **Equator [Maximum velocity boost], facing east**. They also have to **face their desire destination**, thus having to wait for the **right time period** is crucial in Economical Launching.

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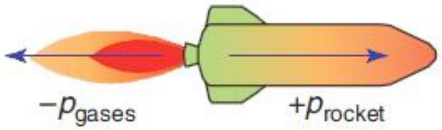
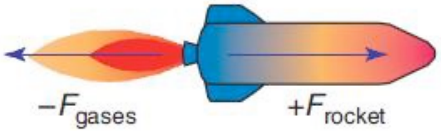
- analyse the changing acceleration of a rocket during launch in terms of the:
  - Law of Conservation of Momentum
  - forces experienced by astronauts





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- **Newton's 3rd Law/Law of conservation of Momentum:**
  - **Newton's 3rd Law:** for every action, there is an equal and opposite reaction.

Hence, the **thrust and fuel burnt downwards towards Earth, must have an equal and opposite reaction; which it the rocket propelling upwards space.**

  - **Law of Conservation of Momentum:** momentum is conserved an any closed system.

Hence, due to Law of conservation of Momentum, the thrust and fuel burnt downwards towards Earth must to the same [conserved] in the rocket.
Since **initial momentum at rest is 0, at any time upon the launch the total momentum must be 0 [Law of Conservation of Energy].**

$$\Delta mv_{rocket} + \Delta mv_{gases} = 0$$
$$\Delta mv_{rocket} = -\Delta mv_{gases}$$

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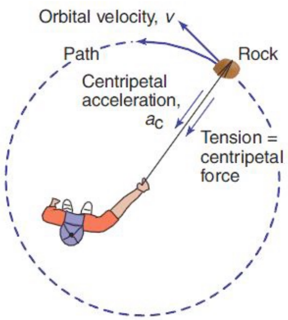
- analyse the forces involved in uniform circular motion for a range of objects, including satellites orbiting the Earth



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- **Uniform circular motion:** moving in a **circular motion with a uniform orbital speed**.
- **Circular motion:** to maintain circular motion the **object must be subjected to a force perpendicular to its velocity at the centre. [Centripetal force].**
- **Uniform orbital velocity:** constant speed in orbital motion.

$$F_c = F_g$$
$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$
$$v = \sqrt{\frac{GM}{r}}$$

- Due to travelling in a circular motion, there it always change in direction, thus stating that there is a force required for it acceleration.

$$a_c = \frac{v^2}{r}$$

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- **Range of objects:**
  - Objects on a string: centripetal force ➔ Tension.
  - Satellites: centripetal force ➔ Gravitational attraction.
  - Car making a turn: centripetal force➔ Friction between tyres and roads.

  When these objects are disconnected with their centripetal force, they will continue in the tangential velocity and fly off.

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- compare qualitatively low Earth and geo-stationary orbits

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<table>
<tr><th></th><th>LEO</th><th>GEO</th></tr>
<tr><td>Altitude</td><td>$\approx 250 - 10\ 000$ km</td><td>$\approx 36\ 000$ km</td></tr>
<tr><td>Orbital Period</td><td>$5 - 90$ mins</td><td>24 hrs
(3075 m/s)</td></tr>
<tr><td>Uses</td><td>▪ Military spy
▪ Hubble telescope
▪ Surveillance satellites
▪ Space shuttle</td><td>▪ Weather forecasting
▪ TV communication
▪ GPS satellites
▪ Mobile communication network</td></tr>
<tr><td>Advantages</td><td>▪ Make communicate with Earth quicker due to shorter distance</td><td>▪ Not affected by atmospheric drag and orbital decay</td></tr>
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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 using Kepler's Law of Periods

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- **Orbital velocity:** the instantaneous velocity of an object in circular motion.
- **Gravitational Constant** $[6.67 \times 10^{-11}]$
- **Kepler's Law of Period:** The ratio between square of the period is proportional to the cube of the radius.

$$v = \frac{d}{T}$$

Since this is dealing with circular motion.

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

Where $d = 2\pi r =$ circumference of a circle.

$$F_c = F_g$$

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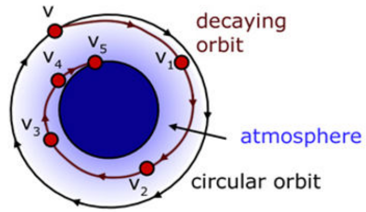
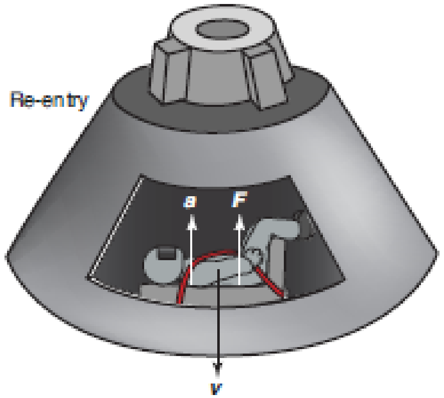
	$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$ $$v^2 = \frac{GM}{r}$$ $$\text{Sub, } v = \frac{2\pi r}{T} \text{ into equation}$$ $$\frac{2\pi r^2}{T} = \frac{GM}{r}$$ $$\frac{4\pi^2 r^2}{T^2} = \frac{GM}{r}$$ $$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$ $\frac{r^3}{T}$, is a constant (K) if the object all orbit the same planet. $r = \text{Radius (m)}$ $T = \text{Period (any given period as long they they are the same)}$ $G = \text{Gravitational constant } (6.67 \times 10^{-11})$ $M = \text{Mass (kg)}$
▪ account for the orbital decay of satellites in low Earth orbit  	▪ **Orbit decay:** Due to the **interaction with the atmosphere**, the object in orbit will interact with the **air particle**. As a result they are subjected to a **friction force**, and lose it velocity. ▪ This is mainly for **satellites in LEO orbit**, as their max altitude of 1000 km will be affected by Earth's atmosphere. ▪ The object in the atmosphere will be subjected to **atmospheric drag, where air particle collide and transforms into heat energy, thus losing energy for the object**. This loses of energy makes the object unable to hold its orbit. Hence **losing altitude**. ▪ As it **lose altitude it also loses GPE, and that lose in GPE is a gain in KE; due to the atmospheric drag, the KE is converted to heat energy.** ▪ **GPE ➔ KE ➔ Heat energy** ▪ The orbit gradually loses speed and altitude and decays as; it is unable to keep the object in object.

- discuss issues associated with safe re-entry into the Earth's atmosphere and landing on the Earth's surface



- **Re-entry**: The **return of a spacecraft into Earth's atmosphere**.
- **Extreme Heat:**
  - Just like orbital decay, spacecraft re-entering to Earth will face **friction force** with the **air particle causing extreme heat**.
  - To prevent spacecrafts from the heat, the design of a **blunt nosed shape** is implemented to **produce shockwaves which are then used to absorb the heat**.
  - Also, the used of **ablation tiles (ceramics) acts a heat shield**, as they **vaporise whilst absorbing the heat,** thus reducing the heat activity.
  - Also, **silica fibre glass tiles** are used as they **contain 90% air.** They act as a **thermal insulator for the spacecraft, dispatching heat of up to 150 000 C**.

- **Angle of Re-entry:**
  - A desired angle must be obtained in order for a safe return for the astronauts.

    $$6.2 \pm 1\,°C$$

    $> 7.2°C$: The spacecraft will **descend at an accelerating rate**, causing **overheating** and a **huge increase in g-force, giving less survival** for the astronauts.

    $< 5.2°C$: The spacecraft will have a chance of **bouncing of the atmosphere**, and that will **waste more fuel**, risking the astronaut's journey.

- **G-force:**
  - G-force is important for re-entry, as humans can't **tolerate a large amount**.
  - To prevent large G-force, the technique **S-bank turns**, is used to minimise the g-force for astronauts, as they **travel in the shape of a 'S'** and hence **increase their distance** rather than going straight. This **increases of distance, reduces the velocity** over the same **given time.**
  - Also, the astronauts are placed **lying facing down horizontally** to prevent the **eyeball in effect.** In doing so their **blood flow should be around their brain**.
  - Astronauts are also, equipped with **contour fibreglass chairs** to hold them firmly in position and to further **reduce the blood flowing away from the brain**.

- **Ionisation Blackout:**
  - Throughout the process of re-entry, come the phrase of **Ionisation Blackout**, where astronauts **communications are blocked** by the **ionised particles created by the heat colliding.**
  - **Radio waves can't penetrate this ionised layer**, hance for the blackout.
  - There is no fixed solution, but the best way to overcome this blackout is to **plan beforehand.**

	▪ **Landing:** – When landing the spacecraft, there are still problems affecting the safety of the spacecraft and the astronauts. – To maximise the safety, **parachutes and retrorockets** are installed to help control the final steps to securely land the spacecraft either on **land** or mainly in the **sea**.
▪ 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	▪ **Optimum angle for re-entry = 6.2 ± 1 °C** ▪ $>$ 7.2°C : Having an angle **greater than 7.2** will cause **severe heating** of the spacecraft and a **high tolerance in G-forc**e, which is not ideal for the **astronaut's safety.** ▪ $<$ 5.2°C : Having an angle **less than 5.2** will cause the spacecraft to **bounce of the Earth's atmosphere (due to the compression of the atmosphere below).** This result gets the astronauts **lose in space**, and a **lose in fuel** for another attempt for re-entry.

Students:	*Notes:*
▪ solve problems and analyse information to calculate the actual velocity of a projectile from its horizontal and vertical components using: $v_x^2 = u_x^2$ $v = u + at$ $v_y^2 = u_y^2 + 2a_y\Delta y$ $\Delta x = u_x t$ $\Delta y = u_y t + \frac{1}{2}a_y t^2$	▪  **Worked example** QUESTION You throw a ball into the air (Figure 1.1.7). You release the ball 1.50 m above the ground, with a speed of 15.0 m s^{-1}, 30.0° above horizontal. The ball eventually hits the ground. Answer the following questions, assuming air resistance is negligible. **a** For how long is the ball in the air before it hits the ground (time of flight)? **b** What is the ball's maximum height? **c** What is the ball's horizontal range? **d** With what velocity does the ball hit the ground? Solve problems and analyse information to calculate the actual velocity of a projectile from its horizontal and vertical components using: $v_x^2 = u_x^2$ $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ $v_y^2 = u_y^2 + 2a_y\Delta y$ $\Delta x = u_x t$ $\Delta y = u_y t + \frac{1}{2}a_y t^2$ Figure 1.1.7 Throwing a ball into the air
▪ perform a first-hand investigation, gather information and analyse	

data to calculate 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	
▪ 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-Pelterie, O'Neill or von Braun	▪ **Robert H. Goddard** – **Known for the development of liquid-fuelled rocketry's.** – **Proved that rockets propelled well in space [vacuum], as other scientists didn't believe it would.** – **Via experiment with airtight chamber, he exactly shows that rocket decreases under atmospheric pressure.** – **First scientist to used liquid-fuelled petroleum and oxygen for combustion.** – **Created energy efficiency via Laval da turbine nozzle which converted energy to hot gas for forward motion. Increased in efficiency [2% - 64%].** – **Researched the use of Gyroscope for stability steering.** **Uses of small vanes near exhaustions allowed predictions of the trajectory of rockets.**
▪ solve problems and analyse information to calculate the centripetal force acting on a satellite undergoing uniform circular motion about the Earth using: $$F = \frac{mv^2}{r}$$	
▪ solve problems and analyse information using: $$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$	▪ Calculate the period of a satellite orbiting around Earth

3. The Solar System is held together by gravity

Students learn to:	*Notes:*
▪ describe a gravitational field in the region surrounding a massive object in terms of its effects on other masses in it	▪ **Gravitational field:** Surrounds all of the mass and experiences a **gravitational force.** **Random Note: We, human have a gravitational field, but the force is so small, it's negligible.** ▪ When an **object to place in the field**, it experiences an **attraction force**. This attraction force is dependent on its mass and centre to centre distance. $$F = \frac{GMm}{r^2}$$ The closer the object to the centre object, the stronger the force. ▪ When calculating the force [vector], make sure to include the direction. 
▪ define Newton's Law of Universal Gravitation: $$F = G\frac{m_1 m_2}{d^2}$$	▪ Newton's Law of Universal Gravitation: $$F = \frac{GMm}{r^2}$$ $\mathrm{F} = \text{Force of the attraction}$ $\mathrm{G} = \text{Gravitational Constant } (6.67 \times 10^{-11})$ $\mathrm{M} = \text{Mass of larger object (kg)}$ $\mathrm{m} = \text{Mass of smaller object (kg)}$ $\mathrm{r} = \text{centre to centre distance of the two mass (m)}$
▪ discuss the importance of Newton's Law of Universal Gravitation in understanding and calculating the motion of satellites	▪ For an object to be in circular motion it must be subjected to a centripetal force, otherwise it would travel straight due to inertia. $$F_c = F_g$$ $$\frac{mv^2}{r} = \frac{GMm}{r^2}$$ $$v = \sqrt{\frac{GM}{r}}$$ $\mathrm{v} = \text{Orbital velocity } (\frac{m}{s^2})$ $\mathrm{G} = \text{Gravitational Constant } (6.67 \times 10^{-11})$ $\mathrm{M} = \text{Mass of central object (kg)}$ $\mathrm{r} = \text{centre to centre distance (m)}$ ▪ From this equation we can conclude that the velocity of the smaller object (satellites) are only dependent their central object's mass

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$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2} = K$$
$$r = \text{Radius (m)}$$
$$T = \text{Period (any given period as long they they are the same)}$$
$$G = \text{Gravitational constant } (6.67 \times 10^{-11})$$
$$M = \text{Mass (kg)}$$
$$K = \text{Kelper's Constant}$$

- Thus, Newton's Law of Universal Gravitation can help us calculate the required velocity to achieve satellites orbits.
- This equation also helps scientists identify, which stars belong with which plants.</td></tr>
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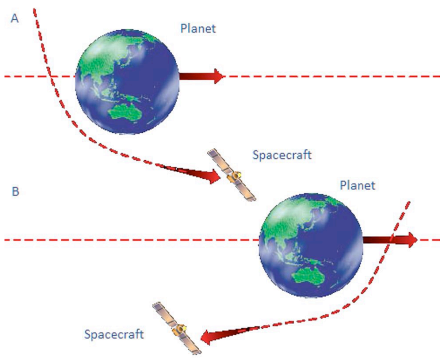
- identify that a slingshot effect can be provided by planets for space probes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- **Slingshot Effect:** A manoeuvre involving the collision of a spacecraft and the gravitational pull. The aim to gain velocity, with little fuel expenditure.
- **AKA: Gravity Assist Manoeuvre, Planetary Swing By.**
- **NOTE: Since the object enters the gravitational pull and gains the KE, when it exits the pull, it will cancel out, thus having no change in velocity. But ...**
- **Process:**
The spacecraft is to travel nearby a planet, until it experiences its gravitational pull. As the spacecraft is captured by the planet's gravity, the KE of the planet is transferred into KE for the spacecraft and hence the spacecraft accelerates, but as swings by and escapes the gravitational pull, it seems to be back to the same entrance velocity. The change in speed is dealt with the orbital velocity relative to the Sun. Only the direction of the spacecraft has changed.
As the planet is orbiting around the Sun, the spacecraft is moving in a [hyperbolic shape] around the planet. Thus we can take that the speed of the spacecraft is moving at its normal velocity relative to the Sun PLUS the velocity of the planet's orbit [NOT the gravitational pull] relative to the Sun.
- **NOTE: In the Planet's frame of reference, the spacecraft is travelling at a constant velocity, but in other frame of reference, the spacecraft has accelerated and increased in velocity.**
- **If the spacecraft is moving behind of the planet then it is accelerates at a different direction.**
- If the spacecraft is moving in front of the planet then it is decelerating at a different direction.
- Throughout this process, it can be known as an elastic collision, Hence [Law of Energy Conservation]:</td></tr>
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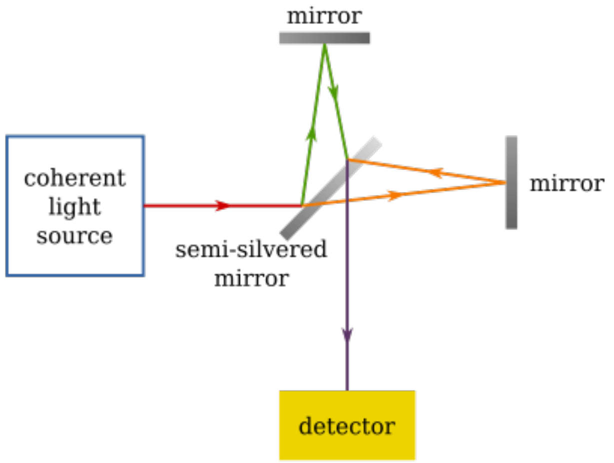
	Kinetic Energy $KE_{Spacecraft} = KE_{Planet}$ $KE_i + KE_f = KE_i + KE_f$ $\frac{1}{2}mv_i + \frac{1}{2}mv_f = \frac{1}{2}mv_i + \frac{1}{2}mv_f$

Students:	*Notes:*
▪ present information and use available evidence to discuss the factors affecting the strength of the gravitational force	$F = \frac{Gm}{r^2}$ ▪ The gravitational force is proportional to the gravitation constant and the mass As Mass increases the force will increase. ▪ The gravitational force is inversely proportional to the to the square of the planet's radius. As radius increase, the force will decrease.
▪ solve problems and analyse information using: $F = G\frac{m_1 m_2}{d^2}$	

4. Current and emerging understanding about time and space has been dependent upon earlier models of the transmission of light	
Students learn to:	*Notes:*
▪ outline the features of the aether model for the transmission of light	▪ Light was known to be a wave [19th Century] ▪ Due to having wavelike properties, it also required a medium ➔ Aether ▪ Aether, Luminiferous Aether, was undetectable and thus had these properties: – **Perfectly transparent** – **Permeate all of space and fill up objects**

	– **High elasticity** – **Low density** – **Stay stationary**
▪ describe and evaluate the Michelson-Morley attempt to measure the relative velocity of the Earth through the aether	**<u>M-M Experiment</u>** ▪ **Aim:** To **measure the relative motion of Earth through Aether using a device called the interferometer**. ▪ **Method:** A single beam of light was allowed to split into two identical components, one was moving in the direction of the aether and the other was moving perpendicular to the aether wind. ▪ **Diagram**:  ▪ **Discussion:** The two beams of light should travel back to the half silvered mirror at slightly different time, as the detector will identify the interfere pattern. The apparatus was rotated 90 degrees to see the effect/direction of the Aether. Result: [Null Result], This experiment failed to answer its aim. Despite the rotation of the apparatus, the different time zone/location and the use of a sensitive interferometer; there was no interfere pattern whatsoever**.**
▪ discuss the role of the Michelson-	▪ **At the time [Limitation on technology]:**

Morley experiments in making determinations about competing theories	– Initially **scientist didn't want to abandon** the theory of the **existence of the Aether**, due to the Laws and Theories purposed for it. – Claimed that **Earth was moving with the Aether, thus was undetectable**. – Stated that the experiment **needed improvement/modifications**. ▪ **[Enhanced technology]:** – With the advancement of technology, they **still** were not able to detect the Aether. – Helped support **Einstein's Relativity**. ▪ **Role:** The notion of a **[Null result]** lead to an insight to the truth that the **aether never existed.** It help **complete Einstein's Postulate**, [The speed of light (c) is constant measured in any inertial frames of reference].
▪ outline the nature of inertial frames of reference	▪ **Galilean's Relativity: The laws of mechanics apply equally in all inertial frames of reference.** ▪ **Non-inertial frames of reference:** One that is **stationary or moving at a constant velocity.** [Motion is **undetectable unless given a reference point].** ▪ **Inertial frames of reference:** One that is **accelerating or changing direction.** [Motion **is detectable without the need of a reference point**].
▪ discuss the principle of relativity	▪ **Principle of relativity: All steady motion is relative and cannot be detected without an outside reference point.** ▪ Implies that there is **no frame of reference** which is **truer than the other**. Merely they are as accurate as each other from their point of reference. **[No absolute frame of reference].** **Two observers** observing **one event** from **different frame of reference**, we would include **both are correct within their reference**. ▪ Also, experiments or observation made inside the inertial frame of reference can't reveal that you are in moving with constant velocity. **String on Train** A string is tied in a train, attached with a ball. Moving at constant motion, the string and ball would appear vertical, but as it accelerates, the string would lean back and thus the ball would move back. This makes the observer able to detect their frame of reference. Thus, there is no way an experiment will be able to not determine if you are in any inertial/ non-inertial frame of reference, due to the principle of relativity.
▪ describe the significance of Einstein's assumption of the	▪ Einstein's Postulate: **The speed of light is constant measured in any inertial frame of reference.** ▪ The speed of light **must be constant** to hold the **principle of relativity true**.

constancy of the speed of light	If C **isn't constant** then, **observers** will be **able to detect their frame of reference** and thus **violate the principle** [which we can't have]. ▪ It could be back up by the **M-M experiment**, as both the beam of lights travel back at the same time, when ever and where ever, in any inertial frame of reference. ▪ For Light to travel at a constant speed[$c = 3 \times 10^8$ m/s], **time and distance must be relative**. [Due to light being a velocity for equation $c = \frac{d}{t}$] ▪ In order for the relativity to hold true, Einstein postulated: **The laws of physic applied equally in all inertial frames of reference**. Meaning that **time, mass, distance** will have to change in order to hold the speed of light true. ▪ **Einstein's Two Postulates:** – **The speed of light is constant measured on any inertial frames of reference** – **The laws of physic apply equally in all inertial frames of reference.**
▪ identify that if c is constant then space and time become relative	▪ **Newtonian Theory** showed **distance and time were constant entities**, leading to **velocity being relative**. But we took the **speed of light [stated early that it was constant], distance and time must be relative quantities to make up the constancy of light. ➔ Space-time continuum.** ▪ Means that we no long define quantities by space but also time **[4 dimension]** **Space coordinates ➔ X, Y, Z [3D]** **Time [1D]** Thus totally into 4D. ▪ Via equation $\text{Velocity} = \frac{\text{distance}}{\text{Time}}$, we can replace the speed of light as velocity $$\therefore 3 \times 10^8 = \frac{\text{distance}}{\text{Time}}$$ Hence, it can be concluded that in order to keep 3×10^8 constant, either distance or time [depending on the frame of reference] must be altered.
▪ discuss the concept that length standards are defined in terms of time in contrast to the original metre standard	▪ **One metre** was first known as $\frac{1}{10\,000\,000}$ **distance from the equator to the North Pole**. ▪ Soon one metre was made into the **distance between the metal bars** located in **Paris**. ▪ Due to the constant velocity of light, we took **one metre as the distance light travelled in one second.** $$3 \times 10^8 = \frac{1}{t}$$

	$$\therefore \text{distance for one meter} = \frac{1}{3 \times 10^8}$$
▪ explain qualitatively and quantitatively the consequence of special relativity in relation to: – the relativity of simultaneity – the equivalence between mass and energy – length contraction – time dilation – mass dilation	▪ **Consequences [Applies to relativistic speeds]:** – **The relativity of simultaneity:** If one observer sees **two simultaneous events** in one frame of reference, it **may differ** for another observer in **different frame of reference** from relative motion to the first. **Example: Einstein's Thought Experiment On Train With Sensory Doors** – **The equivalence between mass and energy:** Energy applied to the object makes the object accelerate and hence moves it faster. **[work]** But when work done to an object at light speed; it **can't accelerate** it **[since the speed of light is maximum universal speed].** Therefore **energy is converted to mass** and thus **more energy** is needed to **move the object and thus more energy, and it keeps going.[Vice versa: Energy can convert to Mass]** We can say Mass dilation due to this. Equation given by: $$E = E_k + mc^2$$ $$\text{But at rest point } E_k = 0$$ $$E = mc^2$$ Now the **Law of conservation of Mass**, **Law of conservation of Energy** is now **replaced as Law of conservation of Mass-Energy.** Example via **Nuclear Fission Reaction**: As a **matter collides** with an **Anti-matter** at near **light speed**, we can take it as **mass colliding** with **mass** at near light speed light. As a result to this **collision of tiny mass**, at light speed, it gives of a **massive amount of energy**. **[Atom Bombs].** – **Length contraction:** As individual now perceive **time as relative quantities**, length contraction is factored in to make up for the distance it travels. Length of the contraction only happens to the **direction of the object motion [It doesn't affect the height of the object].** Also takes into effect if the observer is from an external frame of reference. $[L_v]$ Length will contract depending on it relativistic speeds. ➔ **Due to the short time it takes to travel a long distance. The length of the object will contract to suit the situation.** Calculated via equation:

	$$L_v = L_o\sqrt{1-\frac{v^2}{c^2}}$$ $$L_v = \text{Length percieved from external frame (m)}$$ $$L_o = \text{Length percieved within its rest frame (m)}$$ $$v = \text{Velocity (m/s)}$$ $$c = \text{Speed of light } (3 \times 10^8 \text{ m/s})$$ – **Time dilation:** If **length contracts, then time must dilate [take longer],** in order to **keep light constant.** The **greater** the **velocity**, the **more time dilates.** Example: Einstein's Thought Experiment Calculated via equation: $$t_v = \frac{t_o}{\sqrt{1-\frac{v^2}{c^2}}}$$ $$t_v = \text{Time percieved from external frame (s)}$$ $$t_o = \text{Time percieved within its rest frame (s)}$$ $$v = \text{Velocity (m/s)}$$ $$c = \text{Speed of light } (3 \times 10^8 \text{ m/s})$$ – **Mass dilation:** Mass dilation occurs at relativistic speeds **depending on the work done**. Like the equivalence between mass and energy, **mass dilation [gets heavier]** is due to the energy **[Kinetic Energy] conversion into mass**. **NOTE: Object travelling at near light speed. Energy is put into accelerating the object. But at near light speed, energy is converted to mass, making it more difficult and as a result requires more energy to accelerate the object. This process continues to occur until the mass is infinitely large and the energy required is basically infinite. [It makes travelling at relativistic speed near impossible]** Mass of moving object increases as velocity increases. Calculate via equation: $$m_v = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

	m_v = Mass percieved from external frame (kg) m_o = Mass percieved within its rest frame (kg) v = Velocity (m/s) c = Speed of light (3×10^8 m/s)
▪ discuss the implications of mass increase, time dilation and length contraction for space travel	▪ **Mass Increase:** Mass dilation is when energy is converted to mass, due to its capability to convert to kinetic energy, thus converts to mass, which makes the mass 'indefinitely' increasing. This pose as a risk for humans as they are unable to take all the mass. [Too heavy for life]. Another implication of mass increase is that we can never reach the speed of light. ▪ **Time Dilation:** Time dilation makes time move slowly for the rest frame compared to an observer outside the rest frame. Means that the aging process within the rest frame will also be slower compared to observer. [Twin Paradox] Example of Time Dilation: A time is taking for too reach a star may take less than 4.3 light years to reach compared to an observer, who will see the object 4.3 light years. ▪ **Length Contraction:** Length will become shorter due to it connection with the speed of light. As they speed up, the apparent distance will become shorter, thus requiring less space. In order for the object to fix in the situation, they must contract.

Students:	*Notes:*
▪ gather and process information to interpret the results of the Michelson-Morley experiment	▪ As the experiment of M-M was meant to detect the aether. It's experiment and other variations to increase its reliability and validity all came to one result. Null Result, meaning that the experiment didn't achieve the aim of the experiement. ▪ The information gather concluded that the aether never cease to exist, despite all the relevant thoeries supporting it and light. ▪ This may have reference to a boat analogy where boats travel in different directions but the current of the water will affect their velocity. Assessing the validity and reliability of data from primary and secondary sources.
▪ perform an investigation to help	

distinguish between non-inertial and inertial frames of reference	
▪ analyse and interpret some of Einstein's thought experiments involving mirrors and trains and discuss the relationship between thought and reality	
▪ analyse information to discuss the relationship between theory and the evidence supporting it, using Einstein's predictions based on relativity that were made many years before evidence was available to support it	
▪ solve problems and analyse information using: $E = mc^2$ $l_v = l_0\sqrt{1-\frac{v^2}{c^2}}$ $t_v = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$ $m_v = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$	