National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

Exemplar for Internal Achievement Standard

Physics Level 3

This exemplar supports assessment against:

Achievement Standard 91522

Demonstrate understanding of the application of physics to a selected context

An annotated exemplar is an extract of student evidence, with a commentary, to explain key aspects of the standard. It assists teachers to make assessment judgements at the grade boundaries.

New Zealand Qualifications Authority

To support internal assessment

	Grade Boundary: Low Excellence
1.	For Excellence, a student needs to demonstrate comprehensive understanding of the application of physics to a selected context. This involves linking key physics ideas together to provide a coherent picture of the physics relevant to the selected context. This evidence is from a student's response to the TKI task *Physics in the real world*. This student has applied physics ideas to the context of a person riding on a rollercoaster. This student has analysed how the physics concepts are relevant to the application by linking the key physics ideas of energy conservation for the whole journey (1), centripetal force in a clothoid loop (2), the minimum speed required associated with the feeling of weightlessness (3), and the forces on passengers at different positions in the loop (4). For a more secure Excellence, the student could link the explanation of the key physics ideas of centripetal force and centripetal acceleration to the movement of the real rollercoaster through the loop.

Student 1: Low Excellence

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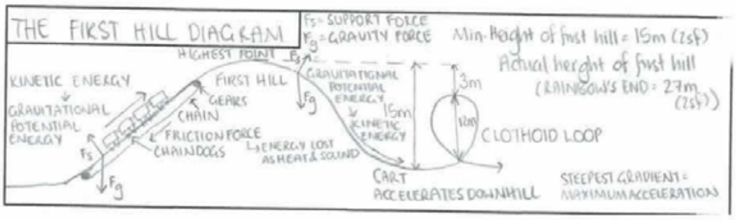
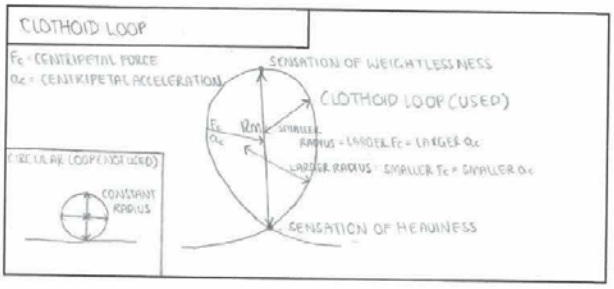
Rollercoasters: The First Hill



The height of a roller coaster's first hill dictates the amount of energy that the train will have (as E_p = mgh) as it travels down the hill towards the first loop, and hence is very important as the carts must have sufficient energy to be able to complete the loop. The law of conservation of energy states that energy can neither be created nor destroyed, so the amount of gravitational potential energy supplied by the first hill will be the maximum kinetic energy ($E_k = ½mv^2$) received by the cart throughout the duration of the ride. At the top of the hill in the Rainbow's End roller coaster, the train starts at a height of 27.4 m (as stated on the Rainbow's End webpage). (1)

Rollercoasters: Loops



The shape used for the loops in roller coasters is known as clothoid. The height of the loop in the Rainbow's End roller coaster is approximately 12 metres, according to my calculations shown below. The clothoid loop is used because it has a constantly changing radius. This helps to ensure that the train does not move too slowly. In the circular loop, the speed (v) must be greater as the train travels into the loop, as a larger centripetal force (F_c) would be required to make the train travel all the way around the loop. $F_c = (mv^2)/r$, thus, for F_c to increase the speed must increase, as the radius (r) of a circular loop is constant, and so is mass (m). It is for this reason that the carts would have to travel faster as they headed into the loop if it was circular, to provide a larger centripetal force. In a clothoid loop, however, the radius is constantly changing. As the radius on the bottom half of the loop (entering and exiting) is greater, the centripetal force does not have to be as large, as $F_c = (mv^2)/r$, so the larger radius means there is a smaller centripetal force required. The larger centripetal force upon entry is not required because the radius at the top of the loop is smaller, and therefore the centripetal force will increase around the top half of the loop. This means that the initial centripetal force can be less for the clothoid loop than the circular loop, as the constant radius of the circular loop means that the centripetal force upon entry is the centripetal force throughout, whereas the changing radius of the clothoid loop means that centripetal force increases around the top half of the loop. This is of benefit to the passengers, as it would be uncomfortable for them to experience large forces through the entire loop, as would be the case for a circular loop, whereas with the clothoid they only experience the large force for the top half of the loop. (2)

The speed of the train is very important, as it must travel at a minimum critical speed to make it all the way around the loop. As shown above, the centripetal force is $F_c = (mv^2)/r$, so thus the force is related to speed. The minimum speed therefore depends on the minimum centripetal force required to keep the train moving around the loop. If the train is travelling at the minimum speed, then the passengers and cars are in freefall at the top of the loop. This means that the passengers feel weightless, and their centripetal acceleration is the acceleration due to gravity, $9.81ms^{-2}$. The sensation of weightlessness is since there is no support force acting in the opposite direction to the gravity force, as weight is only felt when there is an upward support force. During this weightless feeling, their apparent weight is 0 N. (3)

The centripetal force is the force acting towards the centre of a circle, causing an object to follow the track around the circle. The train of a roller coaster therefore needs to have a centripetal force acting on it to keep it moving through the loop. Support force always acts perpendicular to the track, and thus throughout the duration of the loop it is always acting towards the centre of the loop, and hence is the centripetal force. This support force provides a feel for your weight. The gravity force always acts in the downward direction. And at the bottom of the loop, a rider will feel very "weighty" due to the increased normal forces. It is important to realize that the force of gravity and the weight of your body are not changing. Only the magnitude of the supporting normal force is changing.

When at the top of the loop, a rider will feel weightless due to a lack/reduced amount of support force. At the top of the loop, support force is acting on the cart in the same direction as the gravity force, so thus the centripetal force is

$F_S + F_g = F_c$

so $F_S = F_c - F_g$.

If $F_c = F_g$, the support force will be zero.

At the bottom of the loop, the centripetal force is only due to the support force (F_s) acting perpendicular to the track. Gravity (F_g) force is acting downwards, in the opposing direction to the centripetal force (support force).

$F_S - F_g = F_c$

so $F_S = F_c + F_g$.

According to Newton's Third Law, every force has an equal and opposite reaction force. This means that at the bottom of the loop, the upward support force has a reaction force acting downwards. This means that, as the net force is downward, you are experiencing more than 1g (g-forces are explained below), and you feel a sensation of heaviness. (4)

On the way up the first side of the loop, the centripetal force (F_c) is due to the support force (F_s), minus the component of the gravity force (F_g). This is seen as $F_c = F_s$ - comp F_g, where comp F_g is the component of gravity force. This is the case for approximately the first quarter of the loop. However, as the carts reach the top half of the loop, the centripetal force increases in size. This is because $F_c = F_s$ + comp F_g, since both are acting down (though support force is not directly downwards). At the very top of the loop, as explained above, $F_c = F_g + F_S$.
As the train travels on the top half of the loop, but heading downwards after reaching the top of the loop, the centripetal force follows the same equation as travelling up the top quarter of the loop, this being $F_c = F_s$ + comp F_g, as both forces are still generally acting in the downwards direction. As the train continues around the loop, and is again in the bottom half of the loop heading towards the bottom point, the centripetal force becomes the support force minus the component of gravity, as gravity is acting downwards, and support force is acting in the general upward direction.

Rollercoasters: Calculations

The speed of the carts exiting the loop is less than the speed entering the loop, as shown later on in my tracker graphs. My calculations for average speed of the roller coaster at Rainbow's End over the page show a value of 45.9kmh^{-1}, however the Rainbow's End page on parkz.com .au states the roller coaster reaches maximum speeds of 70kmh^{-1}. My calculations also indicate that the approximate height of the loop is 12m. The online Rainbow's End page shows that the first hill (maximum point) reaches a height of 27m. My calculation for the height of the first loop is accurate, as 12m is the height of the loop of the Rainbow's End Corkscrew Coaster (from track to track - not including distance from the track to the ground). My calculation of the height of the first hill gives a lower value than that of the actual first hill, however this is most likely since my calculated value does not take into account the loss of energy as heat and sound due to friction force, as explained below. (1)

Calculation of average speed

d = 600m → 0.600km

t = 47s → 0.013055556 hours

v = d/t

∴ v = 0.6/0.013155556

∴ v = 45.9km^{-1} (3.s.f.)

Calculation of minimum critical speed through the loop

At the top of the loop, the train and passengers are in freefall, and thus the centripetal acceleration is 9.81ms^{-2}.

F = ma

∴ F = 9.81m

$F_c = (mv^2)/r$ r = 12/2 = 6m

∴ 9.81m = $(mv^2)/6$

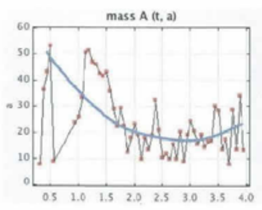
∴ 9.81m x 6 = mv^2

∴ 9.81 x 6 = v^2

∴ v = $\sqrt{(9.81 \times 6)}$ = 7.7ms^{-1} → 28kmh^{-1} (2.s.f.)

My calculation for speed through the loop is less than the average speed and the maximum speed, however this is probably since my calculation is that of the minimum speed required for the train to make it all the way around the loop, not the actual speed of the train through the loop at Rainbow's End.

Sample of tracker use and explanation:



Positive parabola – as the cart heads into the loop, it is at maximum acceleration. It decelerates as it heads upwards towards the top of the loop, as shown by the negative gradient. It reaches the point of the least acceleration at approximately 2.5s. The carts then accelerate again slightly as they exit the loop, however the acceleration out of the loop is far less than acceleration heading into the loop.

	Grade Boundary: High Merit
2.	For Merit, a student needs to demonstrate in-depth understanding of the application of physics to a selected context. This involves explaining how or why the key physics ideas relate to the selected context. This evidence is from a student's response to the TKI task *Physics in the real world*. This student has applied physics ideas to the context of the LASER. This student has explained why the key idea of the Bohr model of the atom explains the stimulated emission of spectra from a LASER (1), and how atoms can be excited and the emitted photons used to amplify the effect (2). To reach Excellence, this student could provide a more coherent picture of the key physics ideas relevant to a working LASER.

Student 2: High Merit

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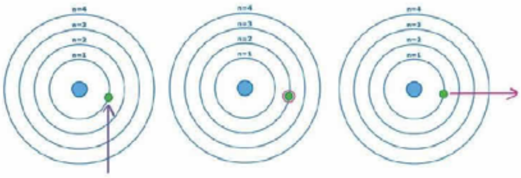
The Bohr Model of the hydrogen atom and electron transitions

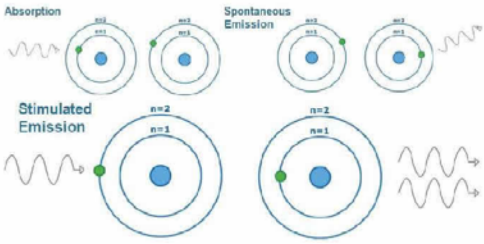


Bohr said that the electron that orbits the hydrogen nucleus can sit at one of multiple 'levels', of certain radii, in which it can orbit the nucleus. However, to sit at a given orbital level, the electron must have the necessary discrete energy value corresponding to that orbital level. The idea of multiple orbital levels contrasts what was previously proposed by Rutherford. This diagram illustrates the process of electron transition between energy levels due to photon emission and absorption.

The left-hand diagram illustrates a photon (purple arrow) being absorbed by an electron (green ball). The central diagram illustrates an electron (green ball with pink circle) which has been excited to a higher energy level (from n=1 to n=2). The right-hand diagram shows the electron emitting a photon (pink arrow). This photon (pink arrow) has energy equal to the difference between energy levels n=1 and n=2. Therefore, the electron has the correct quantised energy value to decay from its excited state (n=2) to its ground state (n=1).

To be specific, the photon required to be emitted/absorbed to cause an electron to transition between n=1 and n=2 of a hydrogen atom is part of the Lyman series and has a wavelength of 122nm. In the diagram above, if the wavelength of the photon (purple arrow) was anything other than 122nm, then the excitation from n=1 to n=2 would never have occurred. A photon must have the exact wavelength, and thus discrete energy value for absorption or emission to occur. An electron cannot remain between two energy levels. This explanation refers specifically to a hydrogen atom. The same principles apply when other elements are used as a lasing medium, although the mathematics is more complex due to greater number of electrons. 1

Spontaneous Emission Versus Stimulated Emission



Generally, an electron in an excited energy state must eventually decay to a lower energy level. As per the principles of electron transition, a photon will be emitted as it decays to that lower level. "This event is called 'spontaneous emission' and the photon [will be] emitted in a random direction and a random phase". Another type of photon emission is called stimulated emission. Consider an electron is orbiting a hydrogen nucleus at energy level n=2 and it is going to decay to energy level n=1. Before the electron undergoes spontaneous emission, it coincidently encounters a photon that has a wavelength of exactly 122 nm. What is likely to occur is a 'stimulated emission'; where a "photon will be emitted at the same wavelength, in exactly the same direction, and with exactly the same phase as the passing photon".

The diagram of a hydrogen atom at top left represents a photon, that must have a 122nm wavelength as per proof 1.2, exciting an electron to a higher state. The diagram at top right represents the spontaneous decay of an electron, causing emission of a photon with a wavelength of 122nm in a random direction and random phase. The bottom diagram represents a 122nm photon coming into contact with an electron, already at n=2, and thus stimulating the emission of a coherent (in-phase), collimated (parallel) light wave with exactly the same wavelength (122nm, as per proof 1.2) as the electron decays to its ground state.

Amplification by Stimulated Emission of Radiation

This diagram represents a group of atoms all in the same excited state. The energy required to initially excite these atoms was provided by an external 'pump' source. A photon interacts with the first atom (the grey ball furthest left) and causes stimulated emission of a coherent photon. "The two coherent photons then interact with the next two atoms in line, and the result is four coherent photons ... At the end of the process, we will have eleven coherent photons, all with identical phase and travelling in the same direction ... In other words, the initial photon has been 'amplified' by a factor of eleven". The 'initiating' photon of stimulated emission is a result of spontaneous emission.

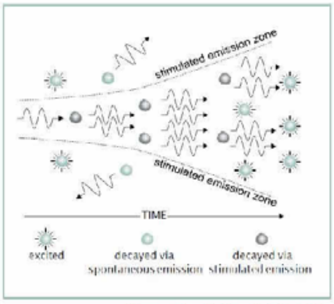


Diagram by Melles Griot, 2009.

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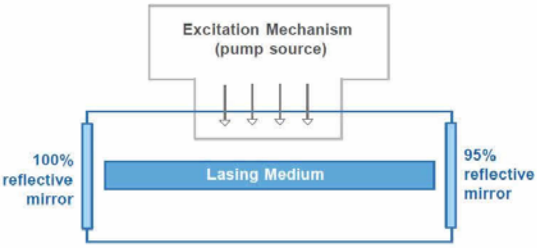
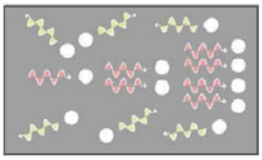
Population Inversion

When an excited atom spontaneously emits the 'initiating' photon for a chain of stimulated emission then that photon could either be absorbed by an atom in its ground state or it could cause stimulated emission of an already-excited atom. For stimulated emission to be sustained, there has to be a greater probability of the initiating photon causing stimulated emission than it being absorbed. For this to occur, a greater proportion of the atoms must already be in the excited state. An external energy source (pump source) is used to sustain this critical proportion of excited atoms compared to ground-state atoms. This is called population inversion.





A look inside the lasing medium.

The diagram represents a model for a LASER. The excitation mechanism provides the energy to ensure that the population of atoms is inverted (i.e. higher proportion are in excited state). The 'initiating' photon is spontaneously emitted in a path perpendicular to the mirrors. This photon causes stimulated emission of photons from the atoms that are continuously being excited by the excitation mechanism. The initial photon has now been 'amplified' and has created a chain of coherent, collimated photons all of the same wavelength.

The mirrors at each end reflect the chain of photons to cause further amplification through creating a standing wave. It is critical that these two mirrors are positioned at a distance that is an exact multiple of half the wavelength of the photons of laser-light. If the length between the mirrors is not a multiple of half the photon wavelength, then a standing wave would cease to occur and the effects of deconstructive interference from out-of-phase photons would gradually weaken the laser-beam. The distance between mirrors being a multiple of half the wavelength is crucial for amplification of laser-light. However, one of the two mirrors is only 95% reflective. This mirror allows a small proportion of the laser-light to pass, while reflecting enough photons to sustain **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. The laser-light that is allowed to pass can then be used for medical, commercial, scientific or recreational purposes.

	Grade Boundary: Low Merit
3.	For Merit, a student needs to demonstrate in-depth understanding of the application of physics to a selected context. This involves explaining how or why the key physics ideas relate to the selected context. This evidence is from a student's response to the TKI task *Physics in the real world*. This student has applied physics ideas to the context of the saxophone. This student has explained why the key idea of standing waves explains the musical notes produced by a saxophone (1), and different harmonics are available and the concept of timbre (2). For a more secure Merit, this student could provide a consideration of the key physics ideas such as use of the wave equation to predict the effective length of tube required for a particular series of harmonics.

Student 3: Low Merit

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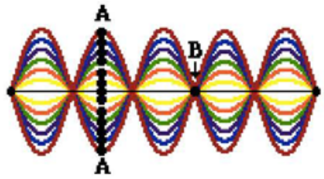
How to play the saxophone PHYSICally?

We can listen to the deep brass tone of the Alto saxophone because standing waves are created when blowing through the bore of the instrument. Why does a note such as high D sound different from a flute to a saxophone, both in the woodwind family? The answer will become simple once you understand the simple basic concepts. You must have knowledge of standing waves, fundamental and overtones, pitch and timbre before you attempt in answering such questions.

Firstly, we should identify what a sound wave is. It is a longitudinal wave. Energy is transferred parallel to the disturbance through the medium, air, without the actual transport of matter however this creates vibration, a repetitive back-and-forth motion of particles. Due to the longitudinal motion of air particles, there are regions of high pressure, compressions, and low pressure, rarefactions, through the medium. These are annotated through the graph on the right. 'A' high pressure of particles. 'B' represents no disturbance moving through it. As you blow through the saxophone, you are creating the disturbance for the first particle to 'pull' and 'push' the second particle and so on. It is because of this vibration within the bore of the instrument that we can hear it. To make a sound, something needs to vibrate.



How fast the particles vibrate inside the medium over a given time is called the frequency. The reed of the saxophone gives off the disturbance which vibrates the interacting particles at frequency and because they 'push' and 'pull' each other, all the particles in the medium are at that frequency. It is important to note that frequency also measured the amount of compressions and rarefactions because the human ear acts as a detector. We are able to associate these fluctuations of air pressures with pitch, highness or lowness of a note. The higher the frequency, the higher the pitch. One octave lower means the frequency was halved. If your musical instrument is said to be out of tone, this means your instrument is out of pitch and at the wrong frequency. This can be adjusted by pulling and pushing the mouthpiece in which changes the length of the bore ever so slightly. All musical instruments have one or a set of natural frequencies which they vibrate. The timbre, quality, of the sound is dependent on how many natural frequencies there is vibrating. If an instrument like the flute has only one natural frequency when vibrated, the sound is purer. The shape of the wave is

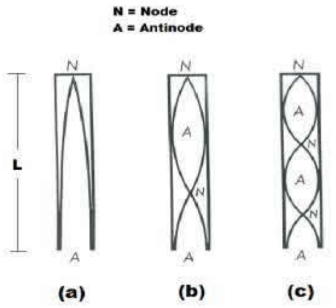
The volume produced by the saxophone can be manipulative to become louder if you blow harder on the saxophone. By blowing harder, you are making the amplitude of the waves bigger. For a wave to have a high amplitude, high displacement of particles, more energy is needed. Therefore, more energy means the sound will carry further. The more you blow, the more the reed moves, and so the more force is put into the saxophone, and thus the more pressure. Pressure is given P=F/A. BOOM

If we want to make a note in a saxophone we have to produce an almost constant frequency. So we have to make a standing wave. A standing wave is produced when a wave travels through the saxophone which is a closed pipe, and the wave bounces back producing resonance. This requires a reflection at the open end. This creates specific points in the medium to appear as if they aren't moving, called nodes. This occurs by a change in impedance at the end of the pipe. This can also be considered from a pressure perspective, where the outside atmosphere pressure does not change but the wave efficiently leaves a 'gap' for the outside air to be fill, and the wave can reflect. Since an external factor essentially drives the vibration, blowing through the instrument, it is classified as a forced vibration and resonance can occur. Only certain frequencies produce resonance thus only certain frequencies produce a standing wave.

Resonance results in a large amplitude, due to the source wave with a certain frequency interfering constructively with the reflected wave. The vibration of the reed from blowing creates several frequencies, several of these will match a natural frequency. Since the waves have the same natural frequency, it is said that the saxophone is forced into a vibrational resonance, and standing waves is formed. Each natural frequency creates a different

standing wave. 'At any frequency other than a harmonic frequency, the interference of reflected and incident waves results in a disturbance of the medium that is irregular and non- repeating.' This rarely happens because objects favor natural frequency with high amplitude due to their minimum energy requirement. Each standing wave corresponds with a harmonic of the instrument, the lowest being called the fundamental frequency. For the saxophone and other musical instruments, these harmonic frequencies are related by ratios and these can contribute to why the saxophone sounds cool. It is important to note that multiple standing waves, all the waves that are travelling back and forth through each other, can be created to make the resultant wave and its pitch. ①

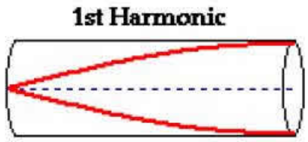
The timbre, quality, of the sound is dependent on how many natural frequencies there is vibrating. If an instrument like the flute has only one natural frequency when vibrated, the sound is pure. The shape of the wave accounts for what the note sounds like, timbre. The shape of the resultant wave results how many harmonic frequencies (and their amplitude). A note such as high D sounds different from a flute to a saxophone because every musical instrument has a different characteristic timbre, each has its own way of creating waves that form different standing waves.



Closed tube - modes of vibration

The saxophone is an example of a closed end pipe; the mouth piece is almost completely sealed by the reed so the pressure is large but there is little air moving through it.
Because at an open end of a pipe the air is free to vibrate, the standing wave will have an antinode. Air particles at the closed end aren't free to move, so is a nodal position. 'Because of the restrictions, the standing wave shapes that can be fitted into the pipes are severely restricted'. They cannot play even harmonics. The harmonic number of a standing wave is the number of times its frequency of the 1st harmonic. In a closed pipe there is no wave that has twice etc., the frequency of the 1st harmonic so these even harmonics do not exist in the saxophone. The saxophone can only play odd harmonics or overtones.

The first harmonic has a node and anti-node. The distance between two nodes is half a wavelength. Therefore, the fundamental frequency (diagram on the right) is equal to one quarter of a wavelength. The second harmonic will be double the 1st harmonic, it will be equal to one half of a wavelength. The second harmonic will result in two nodes on either end, this harmonic is not possible however in the saxophone. If a node is present at the open end, the wave will reflect and a sound will not come from the saxophone. Therefore, the odd harmonics can only be heard, the 3rd, 5th etc. harmonic.



Different notes are played by pushing down on notes, they are arranged at different lengths down the bore of the instrument. By pushing down on certain keys, you are playing a certain note. The note is created by the resultant wave, all the standing waves reflecting back and forth in the medium. By slightly altering the keys pushed down, you are a different set of standing waves, a different resultant wave. If you push no keys down, C# is being played as a result of the different number of standing waves. As the saxophone warms up, the increased air temperature results in an increase in the sound velocity. Velocity equals wavelength times frequency. Since the wavelength is fixed, gives an increase to the frequency. ②

	Grade Boundary: High Achieved
4.	For Achieved, a student needs to demonstrate understanding of the application of physics to a selected context. This involves relating the key physics ideas to the selected context. This evidence is from a student's response to the TKI task *Physics in the real world*. This student has applied physics ideas to the context of rollercoasters. This student has described the link between the key physics idea of the conservation of energy and the starting height of the rollercoaster (1). This student has described the link between the key physics idea of gravitational force, centripetal force and the feeling of "weightlessness" in the context of rollercoasters (2). To reach Merit, this student could provide a complete explanation of how the key physics idea of the conservation of energy is linked to the starting height of the rollercoaster, or give a complete explanation of the links between gravitational force, centripetal force and the feeling of "weightlessness".

Student 4: High Achieved

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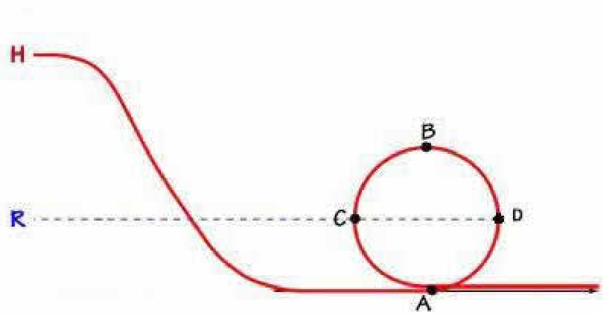
One of biggest attraction at a theme park takes passengers at high speed through a track of loops and twists and hills. The popular theme park attraction is a staple for mainstream theme because of the iconic "weightless" feeling and thrilling speeds. While many have experienced a roller coaster many do not have a full understanding of the physical interaction that happens that they experience such as weightlessness at the top a loop or feeling heavier at the bottom of the loop. A series of physic formulas and concepts can be used to explain these events, Such as Gravitational potential and kinetic energy, Centripetal force, Gravity and friction forces. In this assignment, I will explain the basic forces and energy passenger s and the roller coaster experience in a basic track, from the start of the ride when the coaster is pulled up to a height down then around a loop and then slowed down to the end of a track.

When the passenger first enters a roller coaster the coaster is hooked on the track where is pulled slowly along and up the track where the track reaches a high height, H, where all the energy required to get the rollercoaster though the track. This is important the amount of energy the rollercoaster gained in this height must higher than the energy required to make it through the loop.



This energy at the top of the track is called gravitational potential energy calculated by multiplying the total mass of the coaster and the passenger(s) and the acceleration by gravity (9.81ms^{-1}) (Ep=mgh). When roller coaster falls down to the bottom of the track and converts its potential into kinetic energy E(lin)=½ mv^2 along this whole time some of the energy is lost due to friction and air resistance though this is negligible when designing the track this has to be taken into account. If we ignore or assume there is no friction or air resistance, we know that the coaster will follow the conservation of energy where its states the total energy of an isolated system (roller coaster) cannot be created or destroyed only transferred/converted to other sources such as chemical potential energy or kinetic energy. This is also described by newton's first law of motion (An object in motion remains in motion unless acted on by an outside force). Minimum starting height to keep the cart from falling off at the top of the loop:

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

$$2rmg + \frac{1}{2}mv^2 = mgh \rightarrow 2rmg + \frac{1}{2}mgr = mgh \rightarrow 2r + \frac{1}{2}r = h \rightarrow 4r + r = 2h \rightarrow 5r = 2h \rightarrow \frac{5}{2}r = h$$

(1)

The minimum height the for the cart has to be at least 2.5 time higher than the radius or 1.25 times the height of the diameter of the loop assuming there is no loss of energy due to fraction or external forces.

When the cart is traveling on the loop/circle it experience centripetal force accelerating the cart to the tangentially. Although normally the direction of acceleration due to centripetal force of an object is tangential to its velocity(path) and is constant, We know that as the cart gains height traveling up the loop it's speed decreases so the acceleration experienced is changing proportionally to the velocity (F_c=mv^2/r) F_c proportional to v^2.

Once the cart has made it all the way to the top of the loop(B) it's has converted its energy into gravitational potential energy by displacing itself about the track below (2*r) plus by the energy required to move the cart past the top of the loop. It is important that the design of the roller coaster has the roller coaster moving faster enough once it reaches this point.

This is because if the velocity too low the only force acting it will be gravity causing it to fall off the track (Minimum speed). At this point of the ride the passenger will feel weightlessness because seat no longer applying a force on the passenger. This brief windows of weightlessness will no longer be felt when the passenger when reached at (c) but then will feel heavier because acceleration of gravity and centripetal force will apply a greater force to the passenger until the loop ends at D where the cart is no longer changing direction.
The gravitational potential energy converted into kinetic energy then some gravitational potential energy can be shown here.

$$Ep = mgh = mg2r + ½ mv^2$$

The force and acceleration experienced at each point:

(A) At the point A the kinetic energy(velocity) is reduced and converted into some gravitational potential $\sqrt{\frac{2((mgh)-(mgr))}{m}} = V$ Both gravity and centripetal force are accelerating the cart

(B) At this point the only force accelerating the cart is gravity unless the cart is traveling faster than minimum speed $v^2/r > g \rightarrow v^2 > gr \rightarrow v > \sqrt{gr}$. At this point notice that the mass of the cart does not matter and does not affect the minimum speed

(C) The cart gains some kinetic energy from gravitational potential energy gained from the top of the loop plus by the previous kinetic energy. The velocity at C is equal to A

The roller coaster is famous for its thrilling “weightlessness” feeling felt at the top of a loop or hill. To explain a passenger who feels the perceived “weightlessness” is due to the net forces are 0N there for the reaction force (weight force) which the passenger experience/preserves is 0. So as the passenger approaches the top the one of the two forces the passenger perceives changes (due to change in speed ($F_c = \frac{mv^2}{r}$)). ②

At stage A the cart still has a high velocity so the centripetal force is great and the main force felt by the passenger. When the force of gravity and centripetal force are added, the net force are unbalanced and a reaction force is still felt by the passenger.

When the cart gets to stage B the 2 forces cancel out to bring the net force to 0. Gravity Acceleration (acceleration object down to the ground) +Centripetal Acceleration=0. At this point the Centripetal Acceleration must be equal or greater than the acceleration of gravity or else the cart will start to acceleration down to the ground and fall off the track. Centripetal force must be equal or greater than the force by gravity $Fc \geq 9.81ms^{-2}$ and $9.81ms^{-2} \geq \frac{mv^2}{r} \rightarrow \sqrt{\frac{9.81m}{r}} = v$:
Because $F_R=F_c+F_g=0$ (reaction force equal to Centripetal plus gravity force is equal to 0) F_c+F_C Cancel out because they are both vector quantities pointing in opposite directions (Gravity down and Centripetal up).

A rollercoaster designer would have to consider all of the physics concepts I have mentioned in order to create a loop in a roller coaster track. This and consideration for friction and energy lost while the cart is moving along the track due to friction between the track and the cart and air resistance. The equations I supplied take the track out of reality into a world with no friction affecting the cart. So, a good design would bring the top of the track higher in order to compensate for energy lost on the way down and through the track in order to reach at least the minimum speed to at the top of the loop. In order for the user to feel true “weightlessness” the cart would reach the minimal speed at the top perfectly but due to changing winds and different factor I the designer of the track should never build the track to only this speed at a gust of wind could slow the cart down on the its way onto the loop or while it's only the loop. Also, the designer would need to design the rest of the track so that the cart would not fall off, such as another loop if there were another loop it would need to be at an equal or smaller diameter with consideration of friction at the same height.

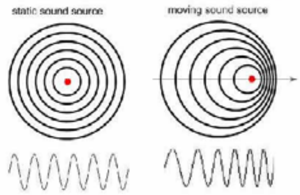
	Grade Boundary: Low Achieved
5.	For Achieved, a student needs to demonstrate understanding of the application of physics to a selected context. This involves relating the key physics ideas to the selected context. This evidence is from a student's response to the TKI task *Physics in the real world*. This student has applied physics ideas to the context of speed cameras. This student has described the link between the key physics idea of the Doppler effect and the use of speed cameras by police and professional sport (1). This student has attempted to describe the link between the key physics idea of Doppler effect and the calculation of the speed of moving objects (2). This student has attempted to describe the link between the key physics idea of Doppler effect and the effect of moving objects on reflected waves (3). For a more secure Achieved, this student could: • relate the key physics idea of how the frequency change associated with the Doppler effect could be used to calculate the speed of an object • clearly describe the key physics idea of the Doppler effect and the effect of moving objects on reflected waves.

Student 5: Low Achieved

Intended for teacher use only

The definition of the Doppler effect is an increase (or decrease) in the frequency of sound, light or other waves as the source and observer move towards (or away from) each other. To relate the Doppler Effect to a real life scenario would be speed cameras/detectors. Speed cameras use the Doppler Effect by using the reflection of microwaves from a moving vehicle to measure the speed that it is going. Police use hand held radars to do the same thing, using the reflection of waves to find the speed of cars. These waves are shifted in frequency by the Doppler Effect, and the beat frequency between the directed and reflected waves provides a measure of the vehicle speed.

[1]To explain the Doppler Effect in the sense of radars, observers from the wave source (Police officer holding radar) will observe the waves from the source at the same frequency as the wave length does not change due to the source being at rest. If the source is moving towards the stationary observer, the frequency will change due to the motion of the source. The waves moving in the same direction as the source will have a shorter wave length and higher frequency due to the motion of the source, but the wave length behind the moving source will be longer but with a lower frequency due to the active source. An example of this is sirens or speed radars. As the stationary observer listens to the source from in front, the frequency will be high but as the source passes the observer the frequency will be lower.



(1)

The frequency changes due to the motion of the source is used with the equation **F=V/ λ**. This equation shows us that the frequency of the wave is dependant of the velocity of the source and we can also see the wavelength of the wave. An example of this is if the source of the waves were moving at a constant speed, then the only thing that can change the frequency is the wavelength. If the source is at a stationary velocity then it doesn't matter if the wavelength is big or small, the frequency can remain the same. Using this theory, we can see how the change in frequency is due to the motion of the source which will create the wavelength making it the Doppler Effect.

When using the Doppler Effect to measure the speed of a car, the reflected waves have different frequency than the incident waves since the vehicle is moving. The size of this frequency shift allows the speed to be recorded. The speed cameras/radars aren't only used to help police officers finding speed of cars, but also for professional spectator sport, for things such as the measurement of bowling speeds in cricket, speed of pitched baseballs, athletes and tennis serves. This speed is given by the following equation:

$$f' = f\left(\frac{v}{v \pm u_s}\right) \quad \text{moving source}$$

$$f' = f\left(\frac{v \pm u_o}{v}\right) \quad \text{moving observer}$$

$$\Delta f = \frac{v}{c} f$$

[2]

Where c is the speed of light, f is the emitted frequency of the radio waves and Δf is the difference in frequency between the radio waves that are emitted and those received back by the gun.[3]

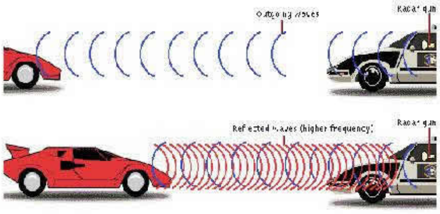
[4]With a 'stationary' radar, the returning waves are received while a signal with a frequency equal to this difference is created by

(2)

[1] http://www.plaindsp.com/unravelling-doppler-effect-plaindsp/
[2] https://en.wikipedia.org/wiki/Radar_gun#Doppler_effect
[3] https://en.wikipedia.org/wiki/Radar_gun#Doppler_effect
[4] https://prezi.com/ldelrjgnt0bu/edwin-hubble-and-the-doppler-effect/

mixing the received radio signal with a little of the transmitted signal. This is the Doppler Effect occurring as the frequencies are bounced off a moving vehicle letting the radar receive the speed. Since the radar gun is the 'observer' and the car is the 'source', the source will be letting off low frequency waves as the source comes to the radar. With the radar moving towards the observer (diagram) the radar will send lower frequency waves whilst the vehicle (source) will be emitting higher frequency waves to the radar for it to read.

With the moving radars, like in police cars, the radar will receive reflected signals from both the target vehicle and stationary background objects such as the road surface, nearby road signs, guard rails and streetlight poles. Instead of the radar gun comparing the signals with the source itself, it will compare the target with the background signals. The frequency difference between the transmitted signal and the background signal will give the true speed of the vehicle (source).



3

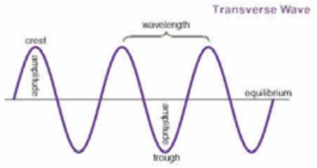
Police radars are a good example of the Doppler Effect and how the returning frequencies and waves can determine the speed of traffic and other activities involving speed recorders. The physics behind the speed radars I thought was interesting as I researched about it as it gave me insight about what happens as the radars transmit waves and showed me about the frequencies and how they change in general terms of the Doppler Effect.

	Grade Boundary: High Not Achieved
6.	For Achieved, a student needs to demonstrate understanding of the application of physics to a selected context. This involves relating the key physics ideas to the selected context. This evidence is from a student's response to the TKI task *Physics in the real world*. This student has applied physics ideas to the context of tsunamis. This student has attempted to link the key physics ideas of different wave parameters changing as a tsunami wave approaches the shore (1). This student has described the link between the key physics ideas of reflection and the creation of standing waves with an attempt to link this to the context (2). To reach Achieved, this student could: • describe clearly how the changing amplitude of the tsunami as the wave approaches the shoreline is due to conservation of energy • describe clearly how wave interference is created by reflection, refraction, diffraction and resonance.

Student 6: High Not Achieved

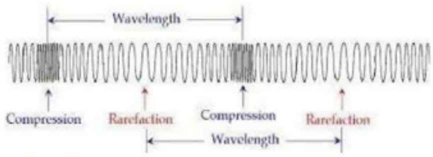
Waves - The interference of waves: Tsunamis

Types of wave: Waves are important because they carry energy without any transfer of matter from place to place. There are two types of wave motion.



Transverse wave: "For transverse waves the displacement of the medium is perpendicular to the direction of the propagation of the wave. A ripple on a pond and a wave on a string are easily visualised transverse waves."[1]

Longitudinal wave: "In longitudinal waves the displacement of the medium is parallel to the propagation of the wave. A wave in a "slinky" is a good visualisation. Sound waves in air are longitudinal waves."[2]

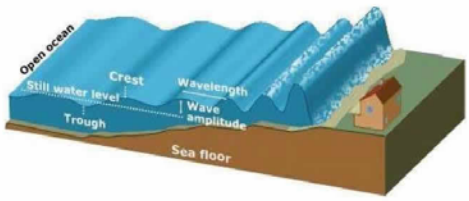


For both transverse and longitudinal waves:

Wavelength, (λ), is the distance between any two corresponding parts of the wave
Amplitude, (A), is the maximum distance the medium moves from the equilibrium position

What wave is a tsunami?

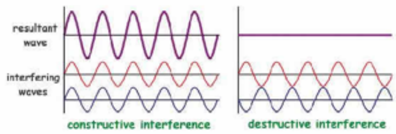
A vertical displacement in the water column at sea creates waves that become tsunamis, such as an earthquake where one tectonic plate slides under another creating a vertical displacement. While at sea these transverse waves have a VERY large wavelength (approximately 500 kilometres), but their overall amplitude is very small (about a meter). Because of the very large wavelength, the wave loses very little energy as it moves along the ocean, thus allowing tsunamis to inflict damage hundreds of km's away. As these waves approach the shore, they start to behave differently and their wavelength becomes smaller and the amplitude becomes much taller. Shallow water compresses the energy as the tsunami moves towards the beach. The wave is moving slow but has tall height, as v and λ decrease, A increases.



(1)

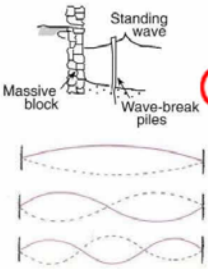
Interference: Combining waves

"When two or more waves pass through each other, the displacements of the medium caused by each individual wave combine to create a resultant wave. This is known as interference."[3] If a crest from one wave happens to line up with the trough of another, they cancel each other out. The particles of the medium have opposite phase and the displacements subtract to give zero displacement, this is called **destructive interference**. If two waves line up crest to crest or trough to trough, they add up. The particles of the medium are in phase and their displacements add to give a crest of double the individual amplitude, this is called **constructive interference**. This is why waves at the beach are all different sizes as well as why tsunamis come as different sizes (But tsunamis size are mainly dependent on the vertical displacement from within the ocean floor). There are lots of different wave groups coming in, and they're interfering with each other in different ways.



Phase: Property of waves definition

If we think of a wave as having peaks and valleys with a zero-crossing between them, the phase of the wave is defined as the distance between the first zero-crossing and the point in space defined as the origin. Two waves with the same frequency are "in phase" if they have the same phase and therefore line up everywhere. Waves with the same frequency but different phases are "out of phase." [4]



(2)

Standing waves result when two equal waves are going in opposite direction and in this case you get the usual up/down motion of the water surface but the waves don't progress. These are common in coastal areas where waves reflect off seawalls. In this case this can happen when a small tsunami hits seawalls. At least 43 percent of Japan's 29,751 kilometre[5] coastline is lined with concrete seawalls or other structures designed to protect the country against high waves, typhoons or even tsunamis. Vertical seawalls are built in particularly exposed situations, like Japan. These reflect wave energy. Under storm conditions or tsunamis a non-breaking standing wave pattern can form, resulting in a stationary wave which moves up and down but does not travel horizontally.

Waves Hitting Things

When a tsunami hits a hard vertical surface (such as a seawall) it is reflected. In other words, the wall pushes the water back just as hard as it got pushed, and sets up waves in the other direction. With constructive interference, you end up with bigger and therefore stronger waves. This is why, in the long run, solid seawalls are not good for saving property from the ocean. You end up creating stronger waves that cause even more erosion. However, seawalls have come under controversy in Japan as their seawalls were overcome by the tsunami's power in 2011. "There is simply no guarantee that seawalls will stop every single tsunami," Nobuo Shuto, an engineer at Tohoku University, told The Economist back in 2014."[6]

Conclusion

A Tsunami is a natural occurring event, there is nothing in our man power to stop a tsunami or to predict one. It is too physically strong. However, there are ways that we can prevent damage from accumulating like it has done before. The use of seawalls to create a standing wave or to prevent the height of a tsunami is one way possible. Different designs of man-made tsunami barriers include building reefs and forests to above-ground and submerged seawalls. In 2005, India began planting casurina and coconut saplings on its coast as a natural barrier against future tsunamis like the 2004 Indian Ocean earthquake. Studies have found that an offshore tsunami wall could reduce tsunami wave heights by up to 83%[7]. Japan formerly had protective walls, many of which were built in the 1930s following a large tsunami. One of these stood up reasonably well against the 2011 tsunami. Most, however, did not. The Economist explains: *"...the evidence for their effectiveness is flimsy. True, Fudai, a village sheltering behind a giant concrete shield, escaped unscathed in 2011. But in the city of Kamaishi a $1.6 billion breakwater, listed in the* 'Guinness Book of Records' *as the world's largest, crumbled on impact. Nearly 90 percent of existing seawalls along the northeast coast suffered a similar fate."*[8] There is not much we can do but to accept the fact that tsunamis are a wave of mass destruction.

1 http://hyperphysics.phy-astr.gsu.edu/hbase/sound/tralon.html
2 http://hyperphysics.phy-astr.gsu.edu/hbase/sound/tralon.html
3 ESA Study Guide Physics Level 3, page 52
4 https://www.learner.org/courses/physics/glossary/definition.html?invariant=phase
5 https://www.cia.gov/library/publications/the-world-factbook/geos/ja.html
6 http://www.sciencealert.com/japan-is-building-a-400-km-sea-wall-to-protect-against-tsunamis
7 http://www.news24.com/World/Archives/TsunamiDisaster/India-builds-tsunami-barrier-20050114
8 http://www.sciencealert.com/japan-is-building-a-400-km-sea-wall-to-protect-against-tsunamis