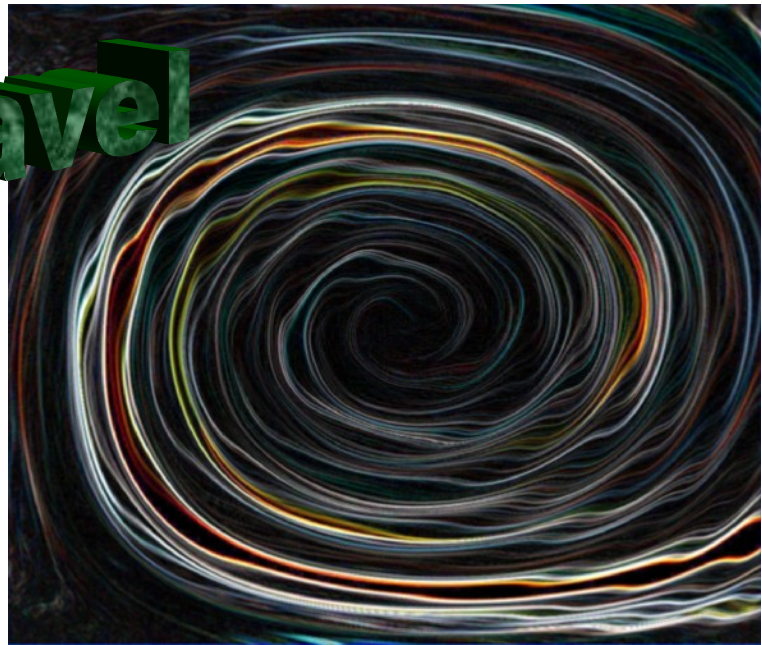




**This module is for secondary students. Energy and Change level 3-6.**

# Time Travel



Your students rarely enjoy challenging their minds more than when presented with time travel conundrums. This module will allow them to actually travel forwards in time! They will also hear the past. A roof mounted solar ripple tank casts shadows on the floor. These images model gravity waves and will be measured in a student-designed experiment.

At school they will make up their own time-travel stories and employing the knowledge that they have gained will analyse the work of others.

As a teacher you will appreciate the background information, which will help you respond to your students questions on the subject. The expected response sheet and levelling rubrics will be invaluable resources in assisting the assessment of your students.





TEACHER USE



These sheets are to provide information to teachers in order that they will be able to stimulate interest and discussion amongst their students.

## Time Stands Still

What's the time? What is time? Is it the tick of a clock, or the rotation of the earth? No these are just things that measure time. A tick is the time it takes the second hand of a clock to move a few millimetres. A year is the time it takes the earth to travel about a billion kilometres around the sun. But what is time? It is hard to say. Maybe it is like a river. We are adrift in the river of time. It is a perverse river: it flows much too fast in the best times but slows agonizingly in traffic jams and when the dentist's drill is grinding away! In extreme moments they say that time stands still. Yet if you measure it with a clock you find that it plods along, irrespective of what's going on.

Why can't we navigate the river of time? If it was possible we could nip into a time boat, start the outboard, and shoot downstream into the future. We could turn around and match our speed to the speed of the river and wait awhile in a freeze frame until you all caught up. Watching the world would be like watching a video. Going upstream at high speed we could zip back to the past, watching you all in fast rewind, running backwards, growing younger, getting unborn while others undied. This would all be fine if all we did was watch.

Suppose we went back upstream watching our great-grandparents undie and then be unborn, same for our great-great grandparents, and so on until we had gone back 30 generations...less than 1000 years. Remember that you have 2 parents, 4 grandparents, 8 great-grandparents, 16 great-greats...and so on. Thirty generations back you have  $2 \times 2 \times 2 \times 2 \dots 30$  times...worth of ancestors: that is A LOT! Try it on a calculator: the answer is 1,073,741,824. More than 1 billion! (The real number of ancestors 30 generations back is not actually quite this high because sometimes people marry cousins, second cousins etc.) But the arithmetic does tell us that everyone from our particular population pool is related if you go far enough back. What has that got to do with time travel?

Now suppose you went back 30 generations in the land of your ancestors. For me it is Britain. I get out of my time boat and walk down a crowded street. I try not to be noticed as I look at these people, knowing that practically every one of them is a direct ancestor of mine. Here are my 30-times great grandparents staring into my face. But a few people notice the weird stranger. One of them, a teenage girl, runs home to tell her parents, missing a gathering with her friends where she would have met her future husband.

Suddenly you have changed the future: everyone's future. In the world where that girl met a different boy 1000 years ago, every strand of relatedness is altered; every single future person is different. Suddenly the you that went in the time boat do not exist, nor do any of the people in

your world today. Your visit to the past has to change only one tiny thing in one person's life and the entire future is changed.

Stephen Hawking, the famous crippled cosmologist who wrote the best selling "Brief History of Time" says we have proof that time travel is impossible, because otherwise we would be deluged with time tourists from the future. I say that is wrong: those people in the future are too smart. They know that any excursion to the past would totally alter the future: they would not do it because they would suddenly cease to exist!

So still we have the question is time travel possible?

Some physicists...notably Kip Thorne of Caltech have claimed that Black Holes and their mysterious cousins, worm holes can allow time travel. Thorne and Hawking have had a famous debate on the topic. Thorne put forward ways of creating worm hole time machines and Hawking shot them down. Hawking showed that such a machine would create infinite amounts of energy: enough reason to be impossible. Yet we know for certain that you can manipulate time in two clear ways. One allows you to look into the past (but you can't go there). The other allows you to slow down the passage of time.

## **Looking into the Past:**

Almost everybody has heard into the past! Can you guess when?

When you hear a thunderclap, you know it always comes after the lightning flash. What we hear is history. If you are alive to hear it you are safe, you didn't get struck by the lightning. The lightning happened a few seconds earlier. Even the flash is a few microseconds into the past. But this is nothing compared with astronomy.

All astronomy is history. Even when you look at the sun, it is 8 minutes in the past. You never see it how it is, only how it was. The nearest star is 4 years into the past, and most of the universe as seen by astronomers is hundreds of millions of years ago. The Hubble Space Telescope can look about 10 billion years into the past. This is because everything is so far away that it took light that long to get here. For the most distant galaxies the light set out on its journey to earth billions of years before the earth and the solar system were formed. So a telescope is time machine, allowing astronomers to unravel the history of the universe.

Physicists hope to be able to time travel even further back to the earliest moments of the birth of the universe. To do this they cannot use ordinary astronomy based on electromagnetic waves. Instead they must use the other spectrum: gravitational waves. Gravitational waves are more like sounds than light. They are vibrations, which travel through space at the speed of light. They have enormous penetrating powers and so can bring us the sound of the big bang itself. The strongest gravitational signals are likely to come from black holes, which are the only things we know of that can slow time to a standstill. Observatories around the world are being linked in a global exploration of gravitational waves. It will take at least 10 years to complete the search. Near Gingin, an hour's drive from the city, the first stage of the key southern hemisphere observatory was opened in March 2000. Its first task is the development of new technology needed to allow all the observatories to achieve the necessary sensitivity. In the future it will be developed into an observatory in its own right.

## Slowing Time.

Einstein proved long ago that time only goes at its fastest pace when objects are in free-fall. He proved theoretically that time goes slower for a ball in your hand than when it is in mid air! Astronauts get the fastest time, and the closer you are to being in orbit (like living in a high rise!) the faster the time goes. That means you get old quicker. You can slow time down by doing anything other than free fall, like driving in endless circles in a Formula 1 race, or even by running around a track. The trouble is that all these effects are tiny. It won't help win any prizes in the Olympics. Yet if we had a rocket ships 10,000 times as powerful as the space shuttle we could use this method of time travel. If we had such a rocket we could go off on a one-year journey and come back to earth in the year 2100.

Even so there is a catch. There is no way back. You could never go back to the year 2000 with a message like "Plant more trees, stop burning coal: the greenhouse effect is destroying the planet".

In spite of the time travel effects being small they can easily be measured with modern clocks. All the measurements prove that Einstein was right.

Yet physicists also know that there is something deeply wrong with Einstein's theory of space, time and gravity, because it is inconsistent with quantum theory. There is a riddle waiting to be solved. The best chance of finding the answer is in studying the gravitational waves from black holes and the big bang.





AT SCHOOL USE

## Notes and Recording



These sheets are for students to use to do activities at school before or after their visit to the GDC.

### Earth during the Jurassic era

“I’ve got to warn myself somehow. I didn’t realise that by travellin’ backwards in time that I would be trapped in the past. The message should be short and to the point. It’s got to survive the years until I see it.”

### Earth present day

Alice McDonald was in a rut. Her calculations had not progressed for weeks. She needed a break, some fresh air, a change of scene. Her laboratory felt like her prison. How many years had she been working in it now? Time seemed unreal to her. Was it two years or twenty-two years - her whole life?

A fellow worker at the university, Jian Xu, had just called her. He was excited about some weird markings that he’d found on a rock. Alice was grateful for the distraction. Maybe the walk to the palaeontology department might clear some cobwebs. The fresh air and sunshine were exhilarating. “How long has it been since I’ve been outside during daylight hours”, she thought. At the doors of his building Jian rushed up and began dragging her while blabbering about the inscriptions.

“Slow down Jian, we’ve got plenty of time. Just what has got you so worked up?”

“We uncovered this rock recently. These faint markings attracted our interest.” said Jian between deep breaths as he tried to calm down.

“They don’t look especially excitin’ to me, please take another couple of breaths and let me in on your discovery.” said Alice, started to feel slightly concerned about the mental health of her friend.

“OK, OK. The rock is from the Jurassic era. There were no humans around when it cooled and solidified. But when we used our computers this morning to enhance the markings, this is what we get.” Jian then clicked the mouse button and an image appeared on the monitor.

Alice looked at it for a full minute in absolute silence. Now it was her turn to be overexcited and blabbering. She ran at full speed back toward her laboratory, screaming “I’ve solved it! Thank you, Jian. You have helped me so much. You don’t know how much. I’ll explain when I get back.”

Jian was stunned for a few seconds, then gathered himself and chased after Alice. By the time he got to her laboratory Alice was nowhere to be seen. The blackboard that she used for her research into time travel had some new chalk marks on the bottom.

$$\frac{WORK}{\Delta t} + uL \neq \beta \Omega \epsilon G u$$

“Well she’s finally done it. She’s solved time travel”, thought Jian. “But I don’t think that she’ll be returning to tell any stories.”

### Earth during the Jurassic era

Alice just finished chiselling the rock. “I hope that I get this message in time”, she thought, as she looked on the words.



1 What did you understand happened in the story? What is the relationship between the message on the rock and the equation on the blackboard? Which was written ‘first’?

2 What flaws/inconsistencies exist in the story on the previous page?

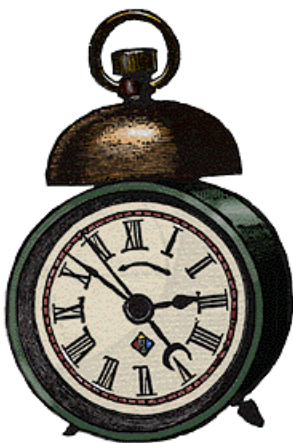
3 What questions are raised by the story?

Time travel stories are a staple of science fiction writers. They offer so many different plot possibilities. Along with many a paradox! You'll also find quite a few flaws in a lot of author's stories.

However many time travel stories are remarkably similar. They all offer some mechanism for time travel. It may be high tech (plausible or fanciful) physics, or a 'simple doorway to another dimension' that our hero stumbles through. The time-traveller may be lucky enough to be able to employ magic or the technology of a friendly alien (but he can't explain it to you – 'Humans aren't ready and would annihilate themselves if they knew'). Using magic or aliens means that the author doesn't need to explain the mechanism for travel.

Another theme that seems common is the plot taking place in a number of time frames at once – remember, time is not absolute! Then there are the questions "Can events be changed by time travel?", "What happens when you bump into a previous version of yourself?", "In fact can more than one version of yourself exist at any one time?", "Can you kill your great-great-great-great grandfather, before he fathers your great-great-great grandfather and still exist yourself?", "Or can you fall in love with, and marry your great-great-great-great grandmother without knowing her relation to you, and become your own great-great-great-great grandfather.", "Can you go backwards in time and use your knowledge of events to become rich by betting on 'sure things'?" etc These make the genre of time travel fiction such a creative and thought provoking one.

Write your own travel into the past story. Are you going to try to mess up 'the future' or are you going to try to have little or no effect on 'the future'? When you're confident that your story will stand up to the scrutiny of others, then swap it with members of your class and allow them to try to find flaws or inconsistencies.





GENERAL USE



## Notes and Recording

These sheets are for students to record their results in various activities, and to use to draw graphs if needed.

*“If time flies, then where does it land?”*



Time travel, wouldn't it be great. You could go into the past and change things. That might cause you a few troubles. What would happen if you did something that stopped your mum and dad conceiving you! Then you wouldn't exist. So you couldn't have travelled back in time to stop your birth. It's a bit confusing, isn't it?

You might decide to go back in time just to observe. That way you wouldn't change anything. Your existence would be safe.

*Picture from*  
[www.pbs.org/wgbh/nova/time/thinktime.html](http://www.pbs.org/wgbh/nova/time/thinktime.html)

You can actually observe the past safely! In fact every time you see something you are seeing how it was in the past, not how it is now.

Light takes some time to travel to your eyes. By the time it reaches you the object you are looking at may have changed. You can only see what it looked like when the light left it. You are observing the past! Normally we don't pay any attention to the difference between what we see and what actually is. It is so slight. Light travels at an immense speed. Every second light can travel 300 000 km.

1. Write the current time here:

When objects are a long distance away then the time that light takes to travel becomes significant. For example when you look at the Sun, you are not seeing what it looks like now. You are seeing what it looked like about 8.4 minutes ago!

2.

<b>Object</b>	<b>Time it takes light to travel from the object to Earth.</b>	<b>Distance in km to the object (multiply the time in seconds by 300 000)</b>	<b>Distance from Earth (light-years)</b>
Moon	1.1991888 seconds		0.000000038
Sun	8.41536 minutes		0.000016
Pluto	5.4200178 hours		0.0006183
Alpha Centauri	4.27 years		4.27

If you completed the third column in the table above, you will see that astronomical distances are huge. Astronomers therefore use a distance measure – the light year, instead of kilometres. One light year is the distance that light will travel during one year. (There are 31557600 seconds in a year. Light travels 467280000000 km in that time!)

You can see pictures of objects in the astronomy image gallery. Their distances from Earth are given in light years. Use the information in the image gallery to complete the following table:

3.

<b>Name of object</b>	<b>How many years into the past we are looking when we see the object</b>	<b>What was happening on Earth when the light left the object?</b>



Light is not the only information that we can receive from the past. Sound also takes a time to reach our ears after an event has occurred. It travels much slower than light, though. This is why you always **see** lightning before you **hear** thunder. At the GDC we have an activity where you can make a sound and then hear the sound arrive some seconds later. When you eventually hear it, you will be listening to yourself in the past!

4. There is a coiled pipe near the entrance of the building. Send yourself a message at one end of the pipe and listen for your message to arrive at the other end of the pipe. If sound travels at approximately 340 metres every second (the speed depends on things like air pressure, temperature, elasticity etc) and the length of pipe is 0.89 km then how many seconds will it take to make the journey?

You can use your answer next time you experience a thunderstorm. When you see lightning count out the seconds until you hear the thunder. For every three seconds you count the lightning is roughly one kilometre away from you.

You thought that you would be doing some time travel in this activity. Looking at, and listening to the past isn't quite what you expected. I mean we do that whenever we watch a delayed telecast on the TV! What if I tell you that you will be travelling into the future in this activity? That seems a bit more exciting, doesn't it?

5. Write down the current time here:

Now turn back to the first page and make a note of the time that you wrote down then. Compare it to the time in the box above. Now look at the current time on your watch. While you were doing all this you have travelled a few seconds forward in time. As far as the you who started this activity is concerned you are reading this now in the future!

*“Time flies like an arrow,  
fruit flies like a banana.”*

The looking and hearing into the past, and forward time travel that you have done are not as exciting as the time travel that occurs in a good sci-fi story.

What is trying to be achieved here at Gingin, and other sites around the world is more exciting. To observe the past events in our universe we cannot listen. Sound waves do not travel through a vacuum. (“In space, no one can hear you scream.” was the slogan for the first ‘Alien’ movie.) Light, and other parts of the electromagnetic spectrum, will let us see very far into the past. But to ‘see’ the earliest moments of the birth of the universe we need to use gravity waves. Because of their enormous penetrating powers they can bring us the ‘sound’ of the big bang itself.

The waves in the GDC solar ripple tank (Exhibit #29) are like gravity waves rolling across the universe. For this activity you need two people, one to follow the waves, the other to time the person following. Take ten measurements and work out the average speed of the waves on the floor.

6. What measurements must you make to determine the speed (in metres per second)?

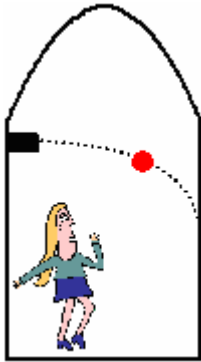
7. Describe how you will perform these measurements to ensure that they are accurate.

8. Record your measurements in the table below:

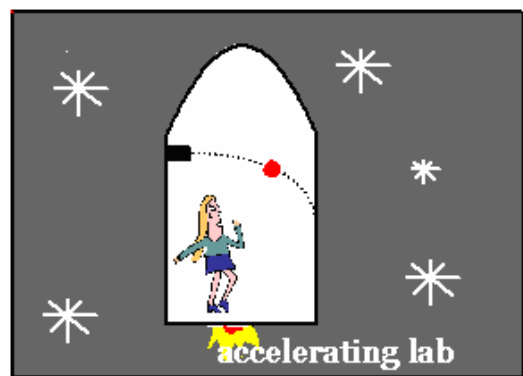
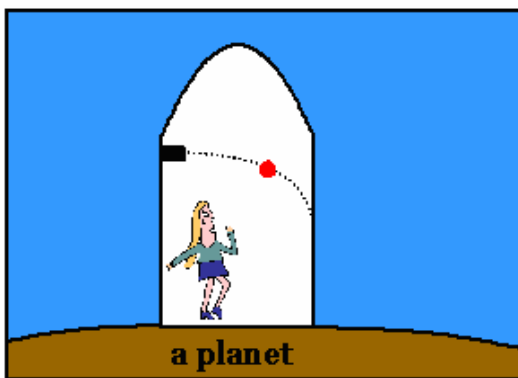
<b>Trial</b>			
<b>1</b>			
<b>2</b>			
<b>3</b>			
<b>4</b>			
<b>5</b>			
<b>6</b>			
<b>7</b>			
<b>8</b>			
<b>9</b>			
<b>10</b>			
<b>average</b>			

9. If you found this too hard to do, how would you change the exhibit?

## APPENDIX. “TIME FOR REFLECTION.”

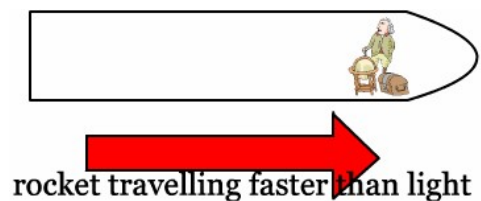


Imagine that you are in a windowless laboratory. You cannot see what is outside. Also imagine that a ball was fired across the laboratory and you saw it ‘fall’ towards the laboratory’s floor as it travelled across. You would not know if the laboratory was on a planet and gravity caused it to ‘fall’, or if your laboratory was accelerating ‘upwards’ and the ball actually went straight across as you moved up. You have no way of knowing which is correct. Because you can’t see outside the laboratory, you have nothing that you can compare the ball’s motion relative to. Einstein’s work on relativity says just that. *“There is no measurement you can make that will tell you whether you are stationary or moving smoothly.”*



Now imagine that you are in a rocket travelling faster than light can travel. (Einstein’s theories say that this is impossible to do in reality, but we can imagine it.) If you looked toward the rear of your ship what would you see? Surely if you are travelling away from the back wall of your craft faster than the light from it is travelling toward you, then you would see nothing. Wouldn’t you? But what about the principle above that says that you can never make an observation that tells you if you are stationary or moving. If you couldn’t see the back of your spaceship that is an observation that tells you that you are in fact moving. Something is wrong!

Einstein realised that time was at the root of this conundrum. You just measured the speed of waves across the floor of the GDC. You used measurements of distance and time. What if time and distance weren’t absolute? What if time could slow down? That would effect our measurements for the speed of light. When you travel extremely fast time does in fact slow down! This has been proved with our most accurate clocks in our fastest jets. Because time (and in fact length) can change when we travel very fast, whenever anyone makes observations or measurements to calculate the speed of light they will always get the same result. You would still be able to see the back wall. You wouldn’t know if you were moving or not.



*“The speed of light is the same for everyone, no matter how fast they are going.”*

(If you are interested in further investigations about the effect that velocity has on time you might try the simulation at <http://www.pbs.org/wgbh/nova/time/think.html> , <http://www.pbs.org/wgbh/nova/einstein/hotsciencetwin/twin1.html> or find other sites.)



TEACHER AND/OR STUDENT USE



## Rubric

These sheets are for teachers and students to assist in the levelling of student work completed while doing the 'Time Travel' module.

### Overarching Learning Outcomes

There are opportunities within the activities in this package for students to demonstrate the following outcomes:

#### OLO 1

Students use language to understand, develop and communicate ideas and information and interact with others.

#### OLO 2

Students select, integrate and apply numerical and spatial concepts and techniques.

#### OLO 6

Students visualise consequences, think laterally, recognise opportunity and potential and are prepared to test options.

#### OLO 7

Students understand and appreciate the physical, biological and technological world and have the knowledge and skills to make decisions in relation to it.

#### OLO 12

Students are self-motivated and confident in their approach to learning and are able to work individually and collaboratively.

The activity involving the measurement of wave velocity would assist you in the levelling of your students in the Investigating Scientifically strand.

## PLANNING

‘Students plan investigations to test ideas about the natural and technological world.’

Level		Pointers	Demonstrated
<b>IS 1.1</b>	The student focuses on problems and responds to teacher’s suggestions and questions.	<ul style="list-style-type: none"> <li>correctly responds to ‘What are you going to investigate’.</li> </ul>	
<b>IS 2.1</b>	The student identifies, given a focus question in a familiar context, some of the variables to be considered.	<ul style="list-style-type: none"> <li>recognises the variables of distance and time.</li> </ul>	
<b>IS 3.1</b>	The student plans for investigations, showing some awareness of the need for fair testing; and makes simple predictions (not guesses) based on personal experience.	<ul style="list-style-type: none"> <li>plans to record measurements of distance and time.</li> </ul>	
<b>IS 4.1</b>	The student identifies the variables to be changed, the variable to be measured and at least one variable to be controlled or, in a descriptive study, plans for the type of observations that need to be made.	<ul style="list-style-type: none"> <li>plans to record measurements of distance and time accurately.</li> </ul>	