Gravity Discovery Centre

Exhibit 15: Under the Stairs

Name: Eddy Currents

Supplied Equipment:
- Aluminium pole

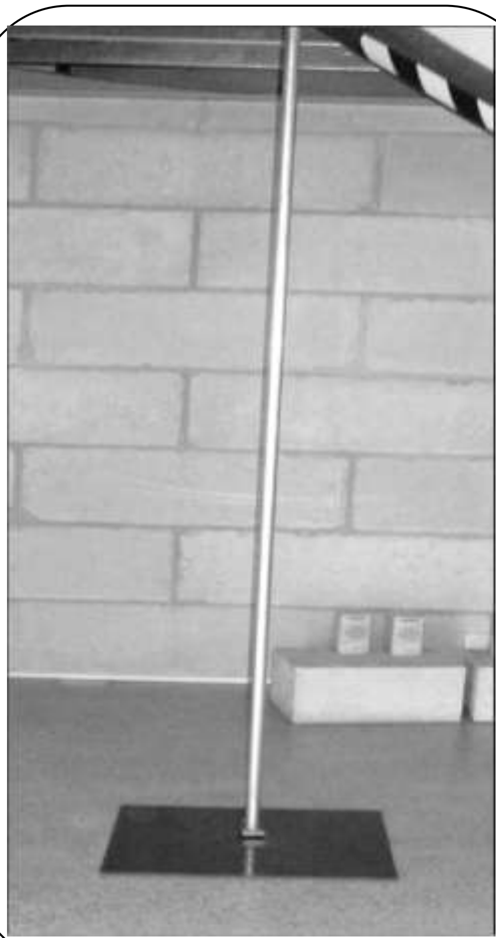
Your own Equipment:
- Tape measure
- Stopwatch
- Calculator
- This booklet

Introduction:

There is an aluminium pole suspended from the ceiling with a strong magnet at its base passing over a copper plate.

Moving magnets make electric currents, and electric currents make magnetism. When a magnet moves above a copper sheet, the magnetic forces act to oppose the motion. We call this "Magnetic Molasses", it feels like honey. Swing the pendulum, and watch it stop.

By simply allowing the rod to travel over the copper plate, the Eddy current build-up is so immense on the conducting copper plate it acts as an instant brake to the moving magnet.



The Task:

Swing the pendulum outwards and measure the height of it above the ground

It has potential energy equal to E = mass x gravity x height = mgh

When you let it go all that energy is converted to kinetic energy which is equal to

$$E = \frac{1}{2} \text{ mass x velocity}^2$$

To find out how fast the pendulum is moving as it hits the edge of the copper we can equate these to formulas.

$$m\,g\,h = \frac{1}{2}\,m\,v^2$$

$$\text{so } v = \sqrt{2gh}$$

You measured the height, and g = 9.8

Calculate the velocity of the pendulum when it will meet the copper plate

The next measurement you will need is how far it moves before it stops.

Raise the pendulum to the agreed height

Release it and measure how far it travelled across the copper before it stopped

We can now use another equation $v^2 - u^2 = 2as$ where v is arriving velocity, u is final velocity, s is distance and a is deceleration

Rearranging we get $a = \frac{v^2 - u^2}{2s} = a = \frac{v^2 - 0^2}{2s}$ so you can find the deceleration

What was the deceleration caused by the Eddy current?

Perform this experiment two more times for varying starting heights

Trail 2

Trial 3

Make a conclusion about how the deceleration varies with the velocity

Velocity and Induction

Extended Investigation

Armed with your conclusions let's put them to the test

At the other end of the building you will find the apparatus pictured at right.

See if your theory works by trying to make the object fall faster by pulling it down quickly.

Now you have a tested conclusion…

What practical purpose could we use this interesting effect for… be creative

What did you find?

What can it be used for?

Light travels at 300000 km per second (1,000,000 times faster).
This means the Moon, Sun and Stars might not exist now.
We see the Moon as it was 1.4 seconds ago, the Sun 8 minutes ago and our closest star (Alpha Centauri) 4.3 years in the past.

Exhibit 16

Name: Time Travel and the Speed of Sound

Supplied Equipment:

- The polytube

Your own Equipment:

- Stopwatch
- Calculator
- This booklet

Introduction:

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 x 2 x 2 x2.... 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 like *The Terminator*...

So still we have the question, *“is time travel possible?”*

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 7 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.

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 10,000 times more powerful than 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.

The Task:

Useful data

The polypipe tube is 1.2 km

The polypipe allows you to make a sound, wait for it to echo through the pipe and hear it again.

Conduct this experiment and find the average time it takes for the sound to return from the past.

Trial 1:

Trial 2:

Trial 3:

Average:

Calculate the speed of sound in air at Gingin today

Thinking Question

When you hit the sound tube at the beginning that happened “now”. When you heard the sound return, did it

a. Return from the past – in other words travel through time?
b. Happen in your new now and so exist in your new “now”

To explain the previous question in another way. When you look at me you see me as I was a fraction of a second ago. So when I speak of what I am doing “now” and what you see “now” are different because our “nows” are different. But then again I don’t know what you are doing “now” just what you were doing a little time ago.

Exhibit 47

Name: The Long Cable

Supplied Equipment:

- Long suspended cable

Your own Equipment:

- stopwatch
- calculator
- tape measure
- this booklet

Introduction:

This experiment allows you to study a Mechanical Wave.

Wikipedia, tells us that a mechanical Wave is “a disturbance that travels through some material or substance called *the medium of the wave*. Mechanical waves are the ideal type of waves as there is no transfer of matter. A mechanical wave requires a medium.”

Like all waves, they have a frequency, period, wavelength and amplitude.

Only the energy propagates; the oscillating material does not move far from its initial equilibrium position; the wave travels by jumping from one particle of the medium to another. Therefore, mechanical waves transport energy and not material.

A mechanical wave requires an initial energy input to be created. Once this initial energy is added, the wave will travel through the medium until all the energy has been transferred.

Transverse waves are waves that cause the medium to vibrate at a 90-degree angle to the direction of the wave. Two parts of the wave are the crest and the trough. The crest is the highest point of the wave and the trough is the lowest. The wavelength is the distance from crest to crest or from trough to trough.

Here at Gingin you can make a wave. Hit the wire with a “karate” chop.

You will see the wave race away and hit the far end of the cable and come back.

The Task:

Using the equipment that you have, find a way to discover the length of the cable.

Length of Cable

Give the cable another Karate chop and find the time the wave takes to travel to the other end and back.

Time

Find the velocity of the wave in steel.

Velocity = distance / time

How does this velocity compare with the velocity of sound and light – these data are to be found elsewhere in this booklet.

Comparison

How did the wave change when it came back?

Two differences

Now hit the wire again and as you see the wave coming back hit the wire again. Watch the waves as they meet. Describe what you see. Do they destroy each other? Include a diagram.

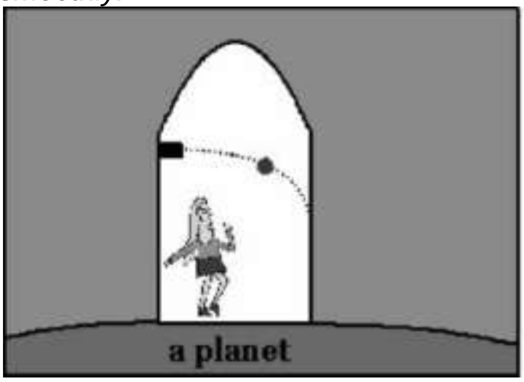
What happened?

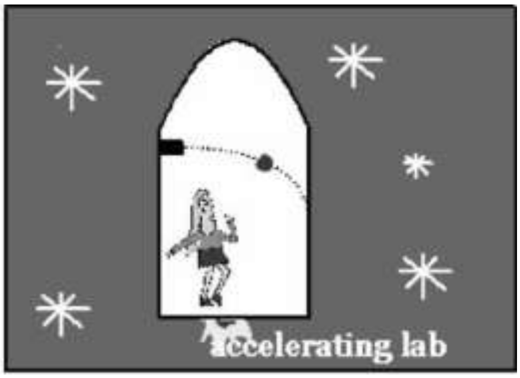
APPENDIX. "TIME FOR REFLECTION."

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.

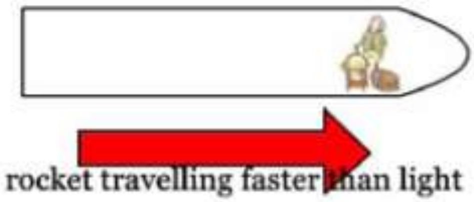
"There is no measurement you can make that will tell you whether you are stationary or moving smoothly."





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 realized 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 affect 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."

Gravity Discovery Centre

Exhibit 30

Name : Lenz's Law and an Inclined Plane

Supplied Equipment:

- Magnetic car
- Inclined plane with various metal plates on it

Your own Equipment:

- Tape measure
- Stopwatch
- Protractor
- Calculator
- This booklet

Introduction:

Lenz's Law states:

An electromagnetic field interacting with a conductor will generate electrical current that induces a counter magnetic field that opposes the magnetic field generating the current.

What does this mean?

It means that when a magnet moves across a conductor [any metal, not just magnetic metal] it causes the electrons in the metal to move in a circular path. This is called *Induction*. But when the electrons move they create another magnetic field in the opposite direction to the first one.

We all know in magnets *like poles repel* and so the moving magnet is suddenly hit with a magnetic field the same as itself and so it slows down because it is repelled by the metal. The faster the metal goes the stronger is the effect.

In this experiment the car has a strong magnet on it and when it runs over metal we can see the effect of magnetic braking – an application of Lenz's Law.

The Task:

We want to find out the size of the magnetic deceleration applied to the car.

When a stationary object falls with gravity $s= ½ at^2$ [s=distance travelled, a=acceleration, t=time]

When rearranged this equation becomes $a=2s/t^2$

When our car runs down the inclined plane it will obey this rule.

When the car runs over wood it has only gravity pulling it down.

Find the length of the ramp – front of car to end of ramp

Length = S =

Conduct three runs and find the average time (seconds) the car takes to run down the ramp **not** running over metal.

1.	2.	3.

Calculate the average acceleration effect of gravity using $a=2s/t^2$

Now try running it over the copper and the aluminium strips and find the average acceleration each time.

Copper only
Conduct three runs and find the average time it takes to run down the ramp

1.	2.	3.	Average

Calculate the new acceleration effect of gravity and so find the retarding effect of Lenz's Law.

$a=2s/t^2$

Aluminium and copper
Conduct three runs and find the average time it takes to run down the ramp

1.	2.	3.	Average

Calculate the new acceleration effect of gravity and so find the retarding effect of Lenz's Law.

$a=2s/t^2$

Suggest an application for this effect in the real world

Extended Question

- Measure the angle the ramp makes to the floor
- Using the relation:

  acceleration = Sin [angle to floor] x 9.8

  you should be able to calculate the effective gravity acceleration the ramp should have provided when the car ran down normally.

Explain why this number differs from what you found