Year 10 Extension Science
Year 11-12 Physics

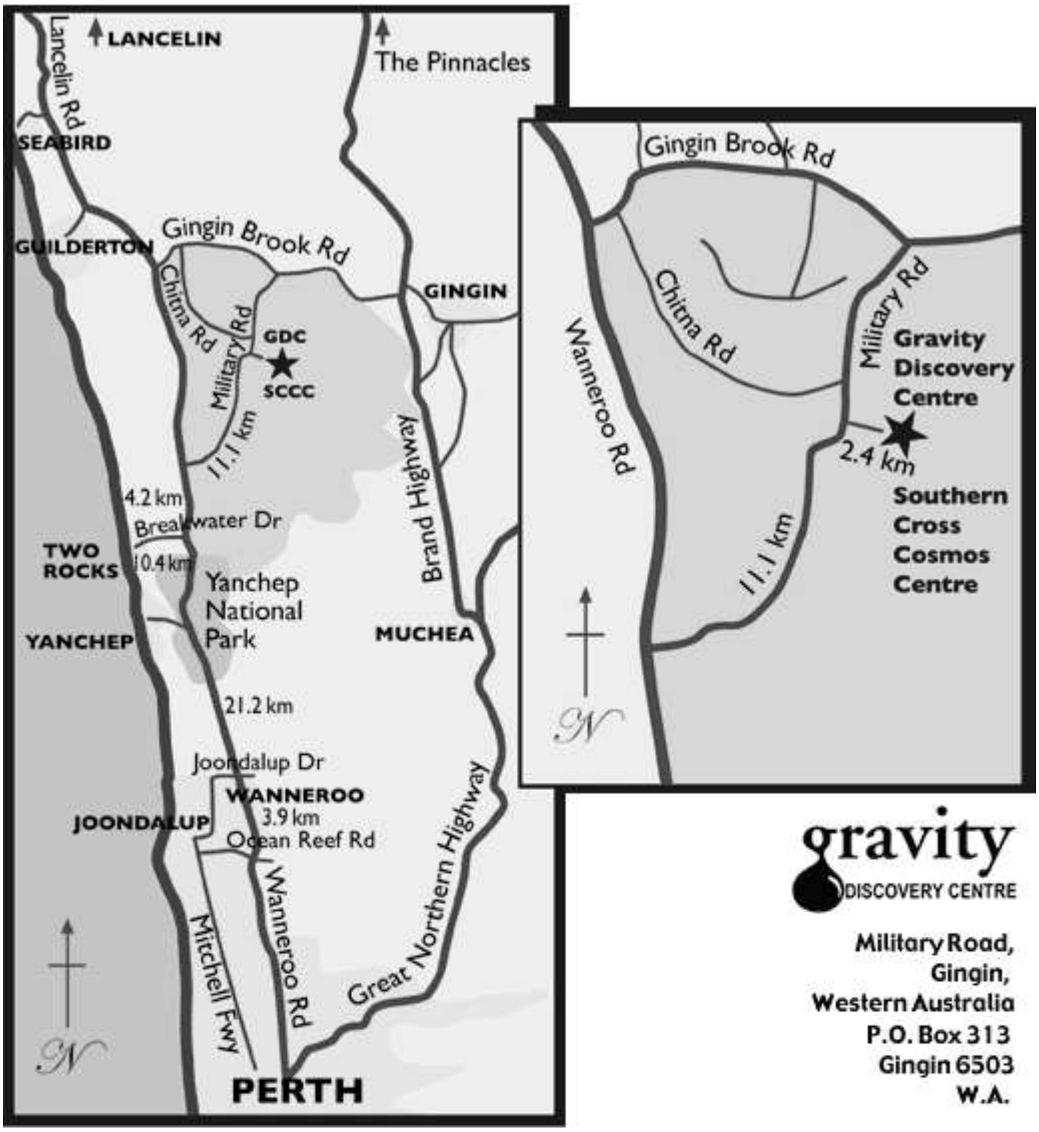
Activities at the Gravity Discovery Centre

This is my book (name)...

gravity DISCOVERY CENTRE

Lyndon Smith

Gravity Discovery Centre



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Gravity Discovery Centre

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Gravity Discovery Centre

Exhibit : Outdoors 31, 32, 33, & 34

Name : Various Pendulums [Pendula!]

Supplied Equipment:
- 3 different Pendulums

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

Introduction:

WHAT IS A PENDULUM
The word comes from the Latin word "Pendulus" which means *hanging*

Something hanging from a fixed point which, when pulled back and released, is free to swing down by force of gravity and then out and up.

The weight at the bottom is called a **"BOB"**

You find pendulums all around you in clocks, swings, and clothing as you move, electric power lines in the wind etc. They provide a great study tool for investigating the scientific method from a low to a very sophisticated level

Harmonic motion is the term used to describe motion that repeats itself over and over. An oscillator is something that makes harmonic motion.

The waves at a beach or a pendulum are good examples of oscillators. Some definitions for you:
- A cycle is one complete back and forth motion.
- The period is the time it takes to complete one full cycle.
- The amplitude is the amount the pendulum moves away from its resting position.

Why is the pendulum scientifically important?

Because

1 it can be used to provide accurate TIME KEEPING note: today we use atomic vibrations for the most accurate clocks.

2 it can be used to measure "g" (the acceleration due to gravity) which is important in determining the shape of the earth and the distribution of materials within it = (the science of geodesy)

the pendulum helps scientists determine “g” force which is affected by:
1) distance from centre of the earth
2) masses attracting upwards e.g. mountains
3) density of matter around you

3. and also it can be used to show that the earth spins.

SAFETY
The bob of the giant pendulum has a large mass. When it is swinging back and forth the energy it is carrying is very large and enough to inflict serious injury. Therefore the following rules must always be followed.

RULES
1. A teacher or supervisor must be present.
2. Instruction must be given to all attending the session.
3. Only one person inside the fence when the bob is in motion.

Experiment 1: Timekeeping

The period of a pendulum is $\boldsymbol{T = 2\pi\sqrt{\frac{l}{g}}}$ where T = period, l = length and g = gravitational acceleration.

This time we will be using the large pendulum.

Length of the pendulum is 13.59m

The value of g is approximately 9.8 in Gingin – we will get a better value in *Experiment 2*

Our Task

To verify that the above formula holds true.

You will see from the above formula that the only things we have to consider are the period and the length of the cable. No matter what the bob weighs or how far we swing it [within reason] the time for each swing will be the same!

Carry out some trials and find the average time for just one swing out and back [the period]

Average Time =

Now assuming your value has errors, how could you do it again to minimize the errors and get a better result?

Using the formula $\boldsymbol{T = 2\pi\sqrt{\frac{l}{g}}}$ calculate the time it should have taken to swing out and back.

What was your percentage error?

Experiment 2: Finding "g"

The previous experiment showed us that the formula $\boldsymbol{T = 2\pi\sqrt{\frac{l}{g}}}$ works so let's use it the other way around. By experiment you have just found the period of the pendulum.

You have the length L you have T so we can rearrange the formula to look like this

$$\boldsymbol{g = \mathrm{L}\,\frac{4\pi^2}{T^2}}$$

What is the value of *g* at Gingin?

How many figures accuracy in your answer? Why?

Experiment 3: Proving that the Earth is spinning using a Foucault Pendulum
(foo- ko pen-je-lem)

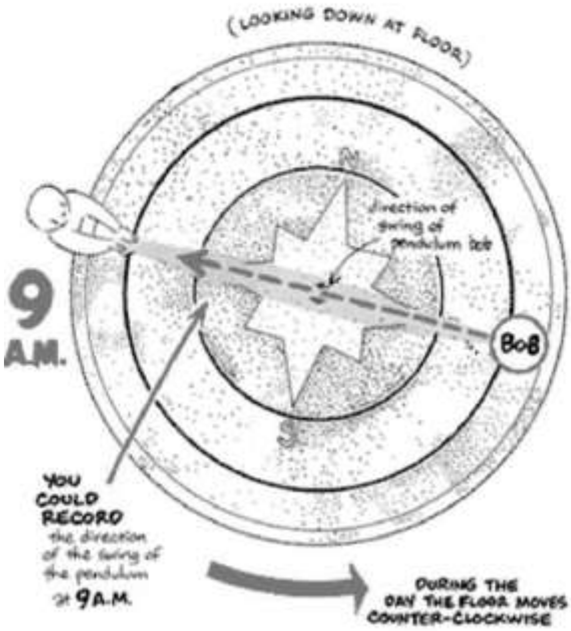
The Foucault Pendulum was invented by French physicist, Jean Bernard Foucault (pronounced *foo-ko)* in 1851 in Paris and was demonstrated for the first time at the world's fair in the Pantheon in Paris.

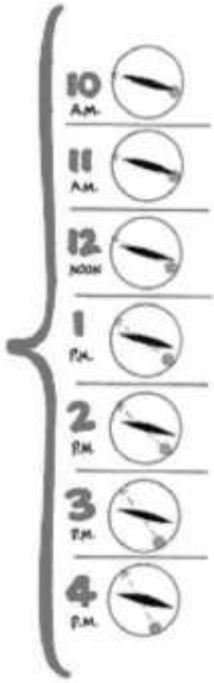
If you set a pendulum swinging from North to South over time it gradually moves from the North South path.

Although the pendulum seems to change its path during the day, it is actually the floor beneath it that is moving.

Centuries ago, Sir Isaac Newton discovered that when a body is set in motion it will move continuously in a straight line from its origin, so long as the body is not interrupted by an outside force that alters its direction. So if the pendulum seems to rotate with respect to the floor and we know there is no force available to make the pendulum rotate and there is no outside force that will interrupt the swing - then - it must be the floor that is rotating. As we know the floor is attached to the earth so it must be the earth that is rotating!

How does the Foucault pendulum work?





At Perth latitude, the floor turns **about 220°** under the pendulum in **about 24 hours** (at South Pole, it would turn a full circle 360°).

Task

To find the deflection at Gingin

You will need to set the pendulum swinging from one side to the other and accurately mark its path of travel. Allow it to oscillate for 30 minutes and determine the amount by which it has moved from the original path

Can you find a way to measure and calculate how many degrees it has moved?

My calculation – include a diagram showing all the measurements you took.

If this is how many degrees it moved in 30 minutes how many will it move in 24 hours?

How the rotation of the earth affects our lives.

- IN PLANE FLIGHT: Navigators must allow for deviation to the right when flying in North in the Northern Hemisphere -- and to left when flying South in the Southern Hemisphere.

- IN SPACE FLIGHT: The rotation of the earth creates special problems on flights to and from the moon.

- WINDS: Winds created by high to low pressure have a left hand deflection that creates cyclones, hurricanes and typhoons, in the Southern Hemisphere. The rotation of earth results in wider distribution of rain over the earth. If not there were no spin, there would be a steady flow of cool air from pole to equator. The cool air would be near the surface; as it is warmed, the air would gradually rise and flow back toward the pole, dropping its water content as it again cooled. This would tend to produce constant rain near the equator and deserts in the northern and southern parts of the world. The rotation of the earth helps break up this north-south cycle by introducing an east (or west) deflection.

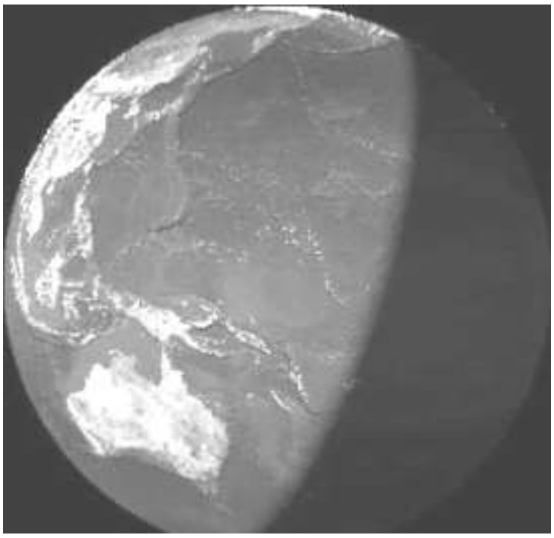
What next

In your own words describe how the Foucault pendulum demonstrates that the earth is turning.

Can you suggest another use of a Foucault pendulum?

Experiment 4

Finding the mass of the Earth: ***This is hard!***



Seems amazing but we can do it

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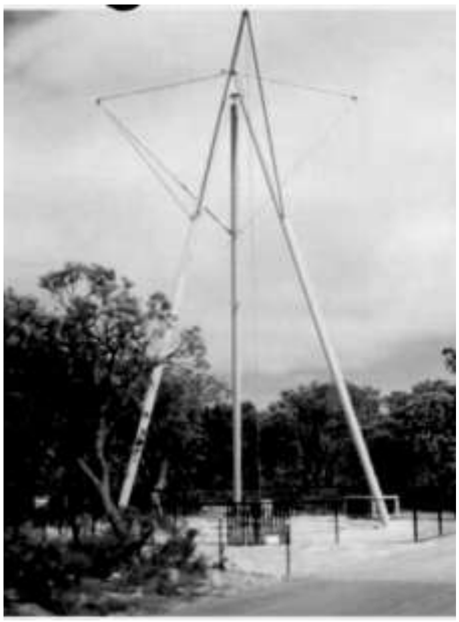
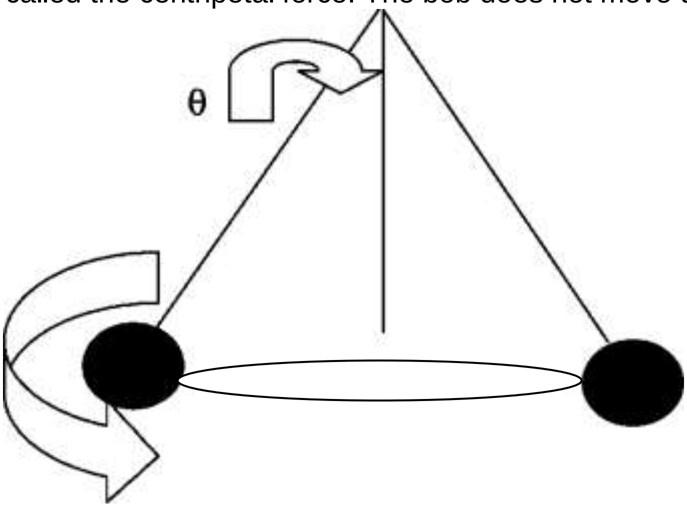


Today we are going to measure the mass of the earth using a conical pendulum. WOW can we really do this?

What is a conical pendulum?
This is a pendulum that is placed in circular orbit. Its period is how long it takes to complete one circle. As it revolves around a central point there are only two forces on it

- the tension in the rope (T) and
- the force of gravity on the bob (mg).

When these are added together the resultant net force is towards the centre of the bob's rotation, in other words it is also called the centripetal force. The bob does not move up or down.



Imagine if the wire broke. The bob would go shooting off in a straight line. This is Newton's First Law.

The centripetal acceleration is the acceleration needed to pull the bob into the circle and stop it flying off in a straight line.

The formula for centripetal acceleration is

$$a = \frac{v^2}{r\ Tan\ \emptyset}$$

Where a = acceleration, m_B is the mass of the bob and v is the velocity of the bob and r is the radius of the pendulum and ∅ is the angle of the wire at the top of the pendulum

Where does this force come from? The answer is it is the force of gravity

Now we can find the gravity acceleration by using

$$a = G\frac{m_e}{r_e^2}$$

Where a = gravitational acceleration, G is a number = 6.67 x 10^{-11}, m_e is the mass of the earth and r_e is the radius of the earth = 6.37 x 10^6 m

If you are really good at algebra you can equate these two and find out that

$$m_e = \frac{4\pi^2\ H\ r_e^2}{T^2\ G}$$

Wow! So we need to find the following things

Time to travel round in a circle once in sec = T = Height of the tower = H = G = 6.67 x 10^{-11} r_e = 6.37 x 10^6 m

Method

- Walk the bob around the pre-drawn circle (this is the coloured tiles forming the circle) until the speed at which it is moving matches the circle drawn. Take care that you have it travelling in a circle and not an oval.
- Time how long it takes to complete 10 revolutions. Find the time for 1 revolution.
- Stop the bob.

Substitute all this into the above equation and you will find the mass of the earth m_e

It is usually accepted that the mass of the earth is 5.9742×10^{24} kg

What was your percentage error?   % Error = [True Value - Experimental Value] ÷ True Value

Why do you think the mass of the bob is so heavy?

This method of measuring the earth's mass is considered indirect. Why?

Experiment 5

Weightlessness!

There is one different pendulum. It is a spring suspended pendulum.

It means in fact that the steel bob is weightless.

Try making it swing like any other pendulum and also have it going up and down at the same time.

What do you observe?

Now the tricky bit. While we agree the bob is weightless, it DOES have inertia.

Inertia comes from the Latin word, "iners", meaning idle, or lazy. Sir Isaac Newton defined inertia in Definition 3 of his *Philosophiæ Naturalis Principia Mathematica*, which states: “The Egyptians and Nubians had an understanding of inertia but much of this history is now lost.”

Inertia is the resistance of an object to a change in its state of motion. The principle of inertia is one of the fundamental principles of classical physics which are used to describe the motion of matter and how it is affected by applied forces.

Here is your question. **How can you prove that a weightless object has inertia?**

How could this phenomenon be life threatening if you were a weightless astronaut?

Experiment 5

***Weird!* The coupled pendulum.**

The final pendulum has two bobs. One is higher than the second. When you set this pendulum swinging you give it energy.

Now let it swing for a while and you will see it goes through various different patterns of behaviour. Let it go for about 5 minutes and study the changes in behaviour.

What did you see?

Now we need an explanation [if you plan on being a Maths genius you could try looking up Wikipedia [“coupled Pendula” – some pretty scary maths there]

We know about energy – here we have a pendulum swinging [moving] and the bobs have mass.

We know Energy = ½ mass x velocity^2 or $E = \frac{1}{2} mv^2$

No calculations are needed, but using this idea can you try to explain what you see when the coupled pendulum undergoes changes in its motion? **What is going on?**