The Virtual Physical Laboratory

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"Great are the works of the Lord;
they are pondered by all who delight in them."
Psalms 111:2

INTRODUCTION

I had the privilege of teaching physics at Hebron School in Ooty in Tamil Nadu, South India between August 2000 and June 2003. It was both a privilege and a challenge, but it enriched my appreciation for my own teachers before me. It is one thing to think you understand something, it is quite another to help someone else understand it.

During my all too brief 'teaching career', I became convinced of the value of interactive simulations as an aid to teaching physics. The 'experiments' can be set up instantly, they work first time, they cannot be 'broken'! Anyone can safely be 'let loose' to investigate for themselves. Every user will quickly reach the level at which they are learning something new. This will be true not only for pupils, but for teachers too; I have certainly learned a lot of physics along the way too.

Although I am no longer actively teaching pupils in school, I have spent thousands of hours over the past sixteen years developing this resource. I have done so in order to help those learning physics as well as those who are already teaching it – to encourage both of them in their on-going learning of this interesting subject.

There seems to be an ever increasing amount of science that we do not yet understand, nevertheless, I am continually fascinated by the amount of natural world around us that is understandable. It is my sincere hope that teachers and students alike will *enjoy* using this resource; that they will explore, 'experiment' and discover for themselves the fascination of physics.

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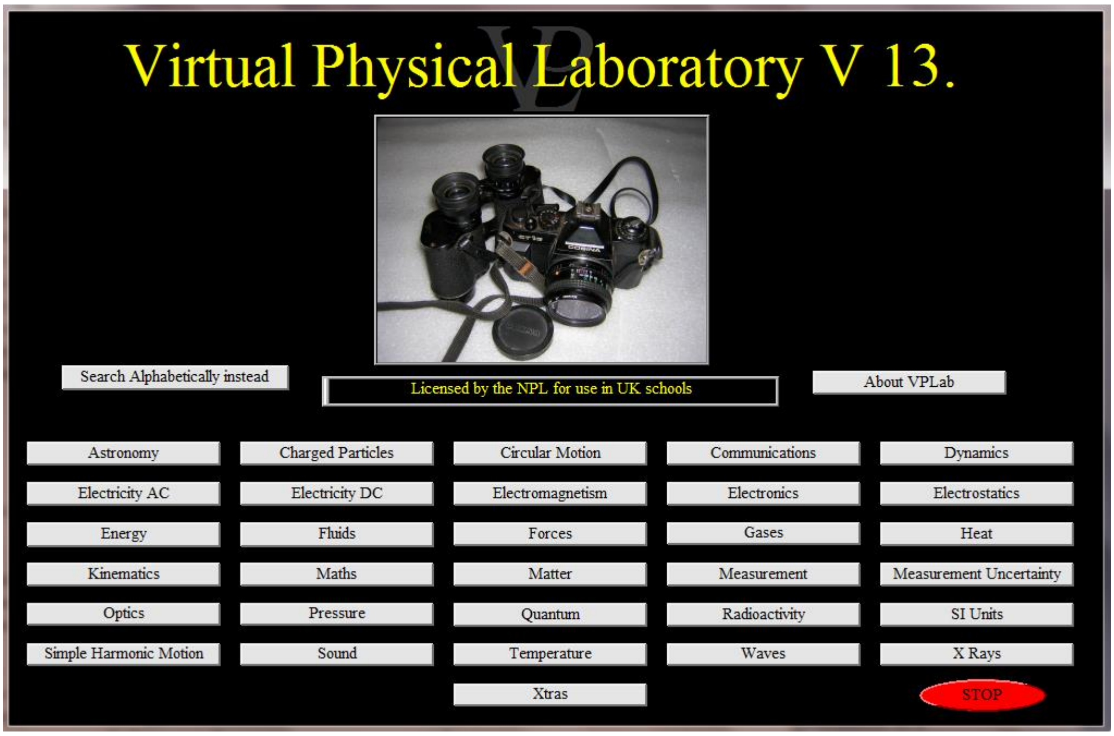


The Virtual Physical Laboratory illustrates and animates most of the topics taught in a modern physics curriculum. Some of the animations and virtual experiments go beyond what is required at school, but are included to stretch the more able pupils.

The Virtual Physical Laboratory is endorsed by The National Physical Laboratory, The Institute of Physics and Cambridge International Examinations. The resource is not tied to any particular syllabus, it has been used successfully in a broad range of curricula worldwide.

The simulations are arranged firstly in alphabetic order of topic, and then in alphabetic order of simulation. With each simulation I have given an indication of the level for which each simulation has been written, (Advanced or Basic) however this is merely indicative. Given the international diversity of curricula it is difficult to state comprehensively what grade a particular simulation is targeted at. I have been designated as ‘Basic’ and others as ‘Advanced’ level. ‘Basic’ level is broadly suitable for 12 to 16 year olds, and ‘Advanced level’ for 17 to 19 year olds. Not all curricula will include all the topics included in this resource, however they are included in this work as a way of covering most eventualities and also as a means to stretch and stimulate the more able pupils.

SIMULATIONS

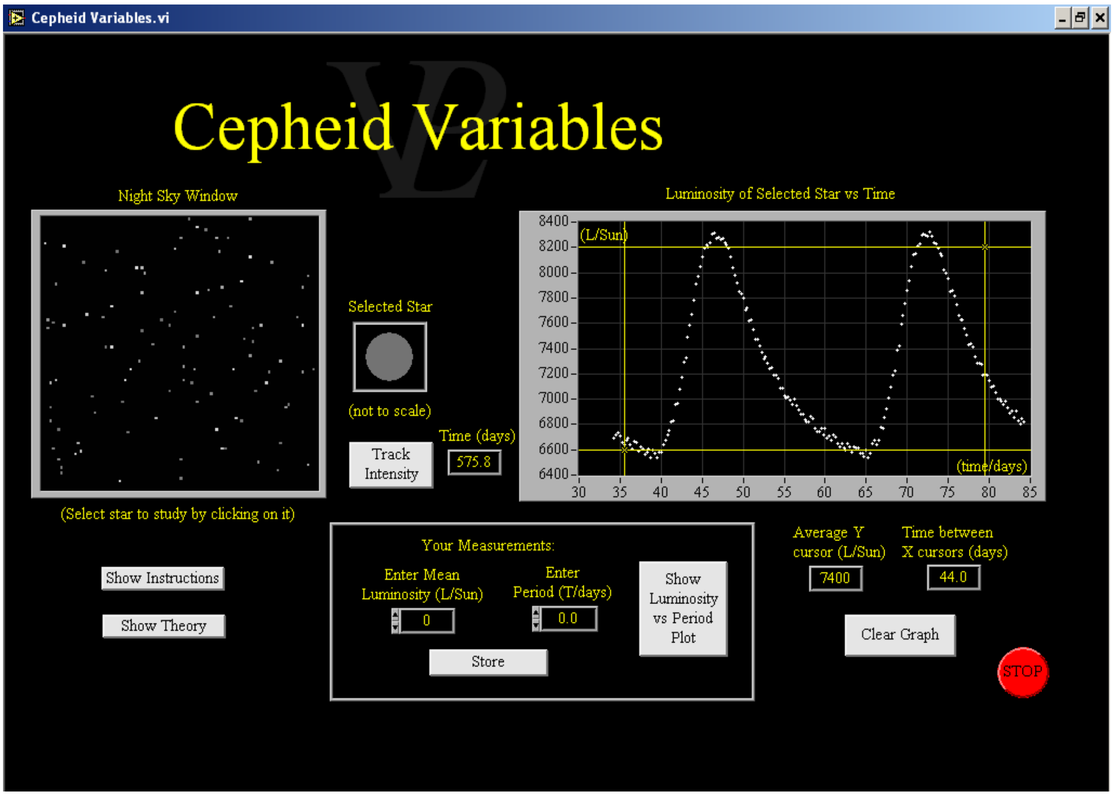
No	Chapter		
	1		**Astronomy**
1		1.1.	Cepheid Variables
2		1.2.	Gravity on Planets
3		1.3.	Day Year
4		1.4.	Hubble
5		1.5.	Kepler
6		1.6.	Lander
7		1.7.	Moon Phases
8		1.8.	Orbits
9		1.9.	Parallax
10		1.10.	Sun Earth Moon
11		1.11.	Tides
		..	
	2	..	**Charged Particles**
12		2.1.	Cathode Ray Oscilloscope Inside
13		2.2.	Cockroft Walton
		2.3.	Diamond Synchrotron
14		2.3.A	Electron Gun
15		2.3.B	Linac
16		2.3.C	Dipole
17		2.3.D	Quadrupole
18		2.3.E	Electromagnetic Waves from Charges
19		2.3.F	Residual Molecules
20		2.3.G	RF Cavity
21		2.3.H	Undulator
		2.4.	ISIS Neutron Source
22		2.4.A	The Ion Source
23		2.4.B	The Vacuum System
24		2.4.C	The Linac
25		2.4.D	The Dipole
26		2.4.E	The Quadrupole
27		2.4.F	The Stripping Foil
28		2.4.G	The Synchrotron
29		2.4.H	The Extraction Kicker
30		2.4.I	The Target
31		2.4.J	The Instruments
32		2.4.K	Muons
33		2.5.	e/m Tube
34		2.6.	Maltese Cross
35		2.7.	Mass Spectrometer

CHAPTER 1
ASTRONOMY

The moon looks different as the month progresses.
What makes it “change shape”?

1.1 Cepheid Variables **Advanced**

This simulation allows the student to carry out his own measurements on the period of the variability of the intensity of different stars, and so determine the relationship between the two.



Cepheids are a type of star whose Luminosity pulsates with a regular period. Edward Piggot first discovered them in 1784! Their periods range from around 1 day up to about 100 days, so the pulsation is difficult to observe by eye. Very careful measurements need to be made in order to detect the variability in Luminosity. The shape of the variation looks a little like a "Shark's Fin" (falling slowly and rising rapidly).

In 1908 Henrietta Swan Leavitt discovered a pattern between the period of the fluctuation of the Luminosity. The higher the Luminosity of a Cepheid, the longer its period becomes.

Measuring the Luminosity of a star is not a trivial thing because the apparent brightness depends on how far away from the observer it is!

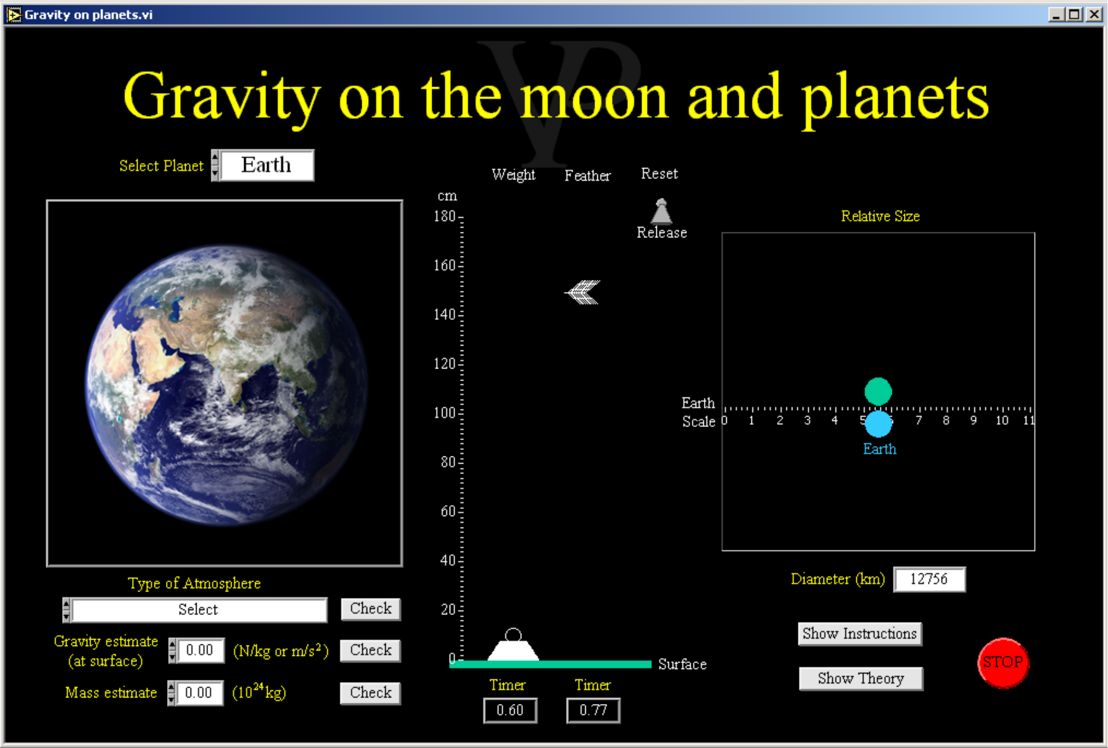
In order to do this study properly it was necessary to first determine the distance to the individual Cepheid stars using the parallax method. Once the distances have been determined it is then possible to convert the brightness measurements observed on Earth in to absolute Luminosity measurements.

The Cepheids studied were much more Luminous than the Sun (typically from 1000 to 30,000 times more Luminous!).

Once the relationship between the period and the Luminosity was found, it enabled astronomers to calculate the Luminosity of a Cepheid simply by measuring its period. (even without needing to know how far away it was!). This gave rise to a method for measuring astronomical distances known as "the standard candle".

1.2 Gravity on Planets **Basic/Advanced**

This simulation enables the pupil to explore the way on which objects fall under gravity on different planets, and so compare the local gravity with that of Earth, and also to determine if there is any atmosphere present.



One of the many things that Isaac Newton discovered is that the force that makes objects fall to the ground is also the force responsible for keeping the Moon orbiting round the Earth.

In the absence of air resistance all objects whether heavy or light would fall at the same rate. However drag due to the atmosphere makes things like feathers fall slower (quickly reaching terminal velocity).

All masses attract each-other with a force which is proportional to the product of their masses, and inversely proportional to the square of the distance between their centres. The constant of proportionality is called the Universal Gravitational constant "G".

$F = G\, M\, m / R^2$

Where $G = 6.67 \times 10$ N kg^{-2} m^{-2}

M = Mass of planet

m = mass of object (or other planet!)

R = Distance between their centres

Near the surface of a planet the gravitational strength is very nearly constant and is simply given the symbol "g". It is possible to measure g directly by dropping an object and measuring the time taken for a given fall using the following equation

$g = (2 \times \text{fall}) / t^2$

Once g has been measured if the diameter or radius of a planet is known it is possible to calculate the mass of the planet by equating as follows: $F = mg$ so

$G\, M\, m / R^2 = mg$ (notice that m cancels out) so $M = g\, R^2 / G$