The Virtual Physical Laboratory

Version 14

June 2018

Dr. John Nunn

www.VPLab.co.uk

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

INTRODUCTION

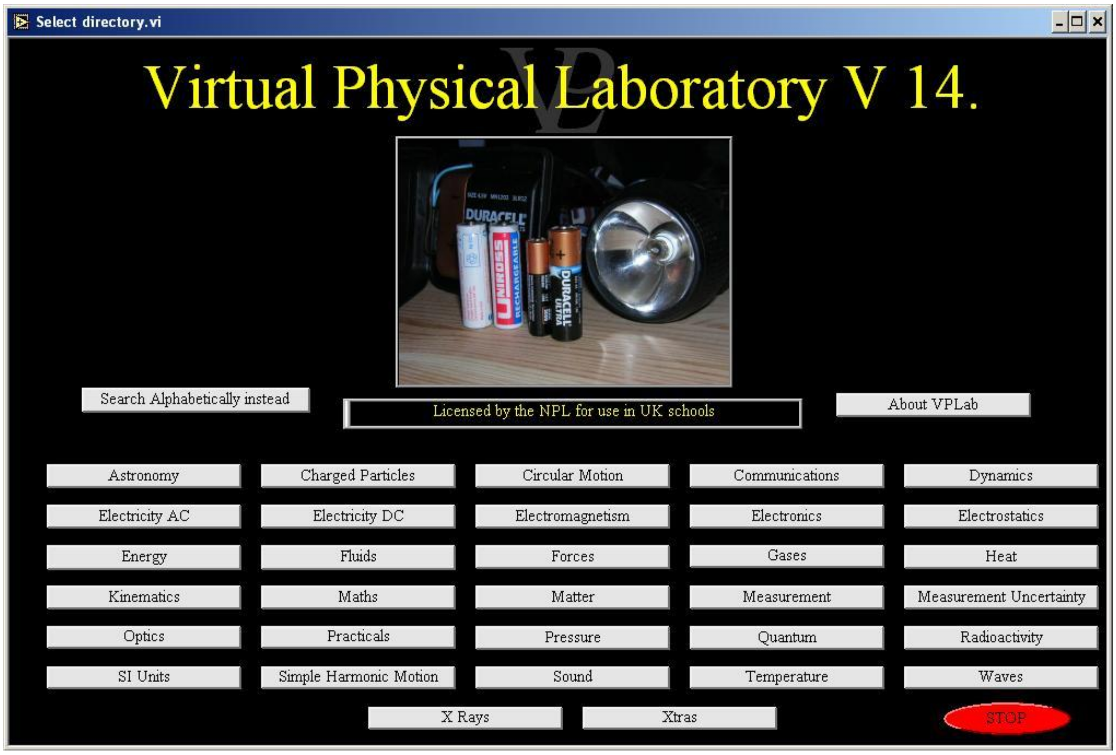
I had the privilege of teaching physics at Hebron School in Ooty in Tamil Nadu, South India between August 2000 and June 2003. It was both a privilege and a challenge, but it enriched my appreciation for my own teachers before me. It is one thing to think you understand something, it is quite another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

John Nunn
June 2018



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.

WHAT IS NEW IN VERSION 14 OF THE VPLab?

As well as a few improvements to simulations that were already present in earlier versions. V14 has a completely new "Practicals" chapter which contains 26 new simulations to help students prepare for the set experiments listed in the curriculum by AQA (12), Edexcel (16) and OCR (11). You will notice that these simulations have minimal instructions as they are designed to illicit the student's own experimental skills and procedures. Any data generated will need to be recorded, plotted and analysed manually - just like normal school experiments. This brings the total number of simulations in the VPLab to 370.

AQA

1 Waves on a string
2 Double Slit Interference
3 Gravity by Free Fall
4 Young's Modulus by Extension
5 Resistivity of Wire Samples
6 EMF and Internal Resistance
7 Simple Harmonic Motion
8 Charles and Boyles Gas Laws
9 Capacitor Charging and Discharging
10 Lorentz Force on Conductor
11 Search Coil in Magnetic Field
12 Gamma Rays Inverse Square

Edexcel

1 Acceleration of Free Fall
2 Resistivity
3 EMF and Internal Resistance
4 Viscosity by Falling Ball
5 Young's Modulus
6 Speed of sound
7 Vibrating Strings
8 Wavelength by Diffraction
9 Force and Momentum
10 Collisions
11 Capacitors
12 Thermistors
13 Latent Heat
14 Pressure and Volume
15 Alpha Beta Gamma
16 Masses on Springs

OCR

1 Acceleration of Free Fall
2 Young Modulus by Extension
3 Resistivity of Metals
4 Potential Divider Circuits
5 Wavelength by Young's Slits
6 Planck's Constant by LEDs
7 Absorption of Alpha, Beta, Gamma
8 Absolute Zero Estimation
9 Capacitor Charging / Discharging
10 Factors affecting Simple Harmonic Motion
11 Specific Heat Capacity

LICENSING OF THE VPLAB

With the exception of the simulations of the Diamond Synchrotron and Isis, the Virtual Physical Laboratory software library is the copyright of VPLab. There are a number of possible licences that can be purchased.

Student license: For private use. Single user and single machine.

Teacher license: For public demonstrations by a teacher. Single machine.

Site License: For use within a single site educational establishment. Multiple concurrent users on networked computers, but excludes pupils personal computers.

VLE License: Using this version, the teacher can select simulations and make them available to his pupils to download from a school based fileshare. The students can then unzip the files on their own computers (typically 2Mb in size) and they can then run them for a period of one week. After that period has expired, that simulation will no longer run. The VLE version of the VPLab needs to be purchased separately.

For further details please visit the website www.vplab.co.uk. For any enquiries please email john.nunn@vplab.co.uk.

INSTALLING THE VIRTUAL PHYSICAL LABORATORY

There are a number of different ways in which you may have received the Virtual Physical Laboratory. It may come as a CD ROM or as a download from a web server.

If you are installing from a CD ROM, simply follow the instructions given on the screen, and if you accept the default options, the software will install itself in C:\program files\Virtual Physical Laboratory. It will also create a shortcut from the start menu under programs called VPLab.

If you received the Software via a download, it will normally download as a compressed or ‘zipped’ folder. The first step must be to ‘unzip’ it. Once this is done, copy the entire contents to a folder of your choice. The top level directory contains a n executable file called VPLab13.exe. Double clicking this executable opens up the program and runs it. You can also create a shortcut and place it on your desk top.

It is important that you preserve the directory structure of the Virtual Physical Laboratory, otherwise the individual simulations will not be found by the top level program.

When a school site licence has been purchased, it is possible to install the software installing the software on a server so that it can be accessed by multiple users. An easy alternative is to place the Virtual Physical Laboratory folder on a shared drive which networked computers can access. In this way any number of users can access the resource at the same time.

CUSTOMISING THE VIRTUAL PHYSICAL LABORATORY

Version 14 of Virtual Physical Laboratory has 370 simulations, and it is easy to lose the ones you are interested in! It is possible to customise the content of the VPLab to make it easier for you to find your way around.

There are two ways in which you may customise your content: Guided and Manual.

Guided method to populate My VPLab

“My VPLab.exe” was written to enable you to keep track of the simulations you want to use.

A - Run My VPLab.exe by double clicking on it.

B - Once it opens up you have the option to “Search whole VPLab Content” or “Search my Customised Content” using the button at the bottom of the screen.

Note: The first time you run My VPLab it will warn you that “You have not yet made any folders in "My VPLab" Search whole VPLab content instead.

C – Press the “Search whole VPLab Content”, and the familiar chapter buttons will appear.

D – Search around for the simulation you want to use, and run it.

E - When you close it, you will see a pop-up box asking “Do you want to copy this last simulation into My VPLab”. If you answer “No” the top level program will return to your last selected chapter. If you answer “Yes” a new window will open up.

F – Initially you will need to create a new folder by pressing the “Create an New Folder” button at the bottom of the screen.

G – A small field will appear for you to enter the name of the folder you want to create. (e.g. Year 11 Term 1). Enter the text and press the “Make it” button. The folder will then appear on the vertical list above.

H – Click in the little tick box to the right of the folder name where you want to save the simulation and press the “save it here” button. (you can only save the simulation into one folder at a time).

I – Press the red “Stop or cancel Last” button to exit from that window and return to the chapter you selected.

J – Press the green “Back” button to return to the top level program with all the chapter buttons.

K – Press the “Search My Customised Content” at the bottom of the screen, and now a button with the folder you have just created should appear (e.g. Year 11 Term 1).

L – Press the new button and it should open up a new window showing its contents (perhaps just the last simulation that you have just placed in to it.)

To add more simulations to this folder, or to create new folders to populate, repeat steps B to L above.

Manual Method to Customise My VPLab.

It is also possible to create your customised sub-folders using your windows explorer. The important thing is to remember to COPY and paste (NOT cut and paste!) otherwise you will gradually start to lose the simulations available from the entire content of the VPLab.

If you have many files you want to move into the customised content directory the manual method is much quicker.

A - In the top level directory of the Virtual Physical Laboratory (where “VPLab8.exe” and “My VPLab.exe” are located), create a new folder called “My VPLab” (if it does not already exist).

B – Inside that folder (“My VPLab”), create a new folder (e.g. “Year 12 Heat”).

C – Open this folder (e.g. Year 12 Heat).

D – The virtual Physical Laboratory in another window.

E – Open the folder containing the chapter you are wanting to draw from (e.g. Heat)

F – COPY the simulation you want and PASTE it into your new folder (e.g. “Year 12 Heat”). Copy as many simulations as you wish into your new folder.

G – IMPORTANT: Make sure you also copy “lvrt.dll” and “lvsound.dll” into your new folder. These two dynamic link files can be found in every chapter folder, and also in the top level directory of the VPLab. (You only need to do this the first time you are populating your new folder).

H – Create as many folders in the “My VPLab” folder, but note that you should not create sub folders within your new folders. The folders may only be one level deep; deeper sub-folders will not be searched by “My VPLab.exe”.

It is possible to use both methods (the guided and the manual) to populate your customised content folders.

After you have finished customising your content, run “My VPLab.exe” to verify that the files are in the places you wanted them to be.

HINTS ON USING THE VIRTUAL PHYSICAL LABORATORY

This section addresses some of the most frequent questions arising out of the use of the Virtual Physical Laboratory in schools and colleges.

1 – Colours of graphs.

The colour red does not project very well, especially narrow red lines on a black background. The solution offered here will work in most cases (but not all).

To change the colour of a line on a graph, right click somewhere inside the graph and select ‘show’ and then ‘legend’ (some graphs already have the legend showing). A box near the top right hand corner of the graph will appear. Right click inside it, and you will be able to select ‘colour’. A colour palette will appear. Select your preferred colour and it will change the plot accordingly. You can then hide the legend box again by right clicking somewhere inside the graph and selecting ‘show’ and selecting ‘legend’ again. Your change will be a temporary one; it will be lost as soon as you quit the simulation.

Changes of colour may also be advisable in some simulations in order to make things easier for colour blind pupils.

Notice also that right clicking on the legend also offers the possibility of changing the ‘linewidth’. This may be a useful change to visually impaired students or where the projection is particularly poor.

2 - Re-scaling graphs, gauges, dials, knobs and sliders.

If a graph, gauge, dial, knob or slider goes out of range, or if you want to change the range in order to improve resolution, left-click and drag over the number at the top (or bottom) of the scale and type the new value you would like to have. The scale should automatically adjust to the new value. Your change will be a temporary one, it will be lost as soon as you quit the simulation.

If you want a graph to automatically re-scale, right click somewhere inside the graph and select ‘AutoScale X’ or ‘AutoScale Y’

3 – Using just one or two simulations without installing the whole package. Simulations can be run independently without recourse to the top level library.

All the files which make up the Virtual Physical Laboratory are contained in a folder on the hard drive (normally in c:\program files\virtual physical laboratory). They are grouped by the same chapter divisions as shown in the tope level program of VPLab.

Create a new directory with a name of your choice using windows explorer. It can be created anywhere on your computer, including on a USB memory stick, or a shared folder on a network.

Two dynamic link libraries are needed for this to work. ‘lvrt.dll’ (normally located in c:\program files\virtual physical laboratory) and ‘lvsound.dll’ (normally located in c:\program files\virtual physical laboratory\sound\data) will need to be <u>copied</u> (not cut

& pasted or dragged) into your new directory. Now copy (not cut & paste, and not drag) any of the simulations you want into your new folder.

These simulations will now run on any machine supporting windows 95 onwards, without needing the full installation. If using a USB memory stick, it can be transported to any other computer, and the simulations can be made to run simply by using windows explorer and double clicking on any of the '*.exe' files that you have selected to copy.

4 – Printing diagrams from the VPLab simulations.

The reason the majority of the VPLab screens are black is that it is much quicker to refresh the screen, and the graphics side of the simulations can run more smoothly. If you want to print part of a screen, the semi-satisfactory way to do this is as follows:

Press "Shift-Print Screen", and then open Microsoft Paintbrush (Normally "Start-Programs-Accessories-Paint). Now press "Ctrl V" (or right click and select 'paste'). The entire screen should have dumped into the Paint Brush window. Click on the select rectangle button of paintbrush to box the part of the image you want. While it is still boxed, click on the 'Image' button at the top of the Paint Brush window and select 'invert colours' All the black should have turned to white, and all the colours are unrecognisable! This might be good enough for your purposes, but if you want to recover the original colours carry out the next step.

Now click on the 'fill with colour' button on the left hand side of the Paint Brush Screen (it looks like a bucket of paint), and select the black colour at the bottom left hand side of the screen and paint all the white back to black again! Then select 'Edit – Select all' (or Ctrl A) and then 'Image-invert colours' again in order to return back to the original colours (without the black). Notice that the screen pieces contained inside hollow letters may need some special attention!

5 – Printing Text from the VPLab simulations.

Unfortunately this cannot be done satisfactorily. It was not a deliberate policy, but just the way it turned out. They can only be dumped as graphics. Sorry!

6 – Exporting experimental data from the VPLab simulations.

This is possible in a limited number of programs. Normally only those that actually acquire data through the audio input of the computer (e.g. AC coupled Oscilloscope the AC Transient Recorder and the Power Logger). The option of exporting simulated data has not been made available as it would not be meaningful in any real sense.

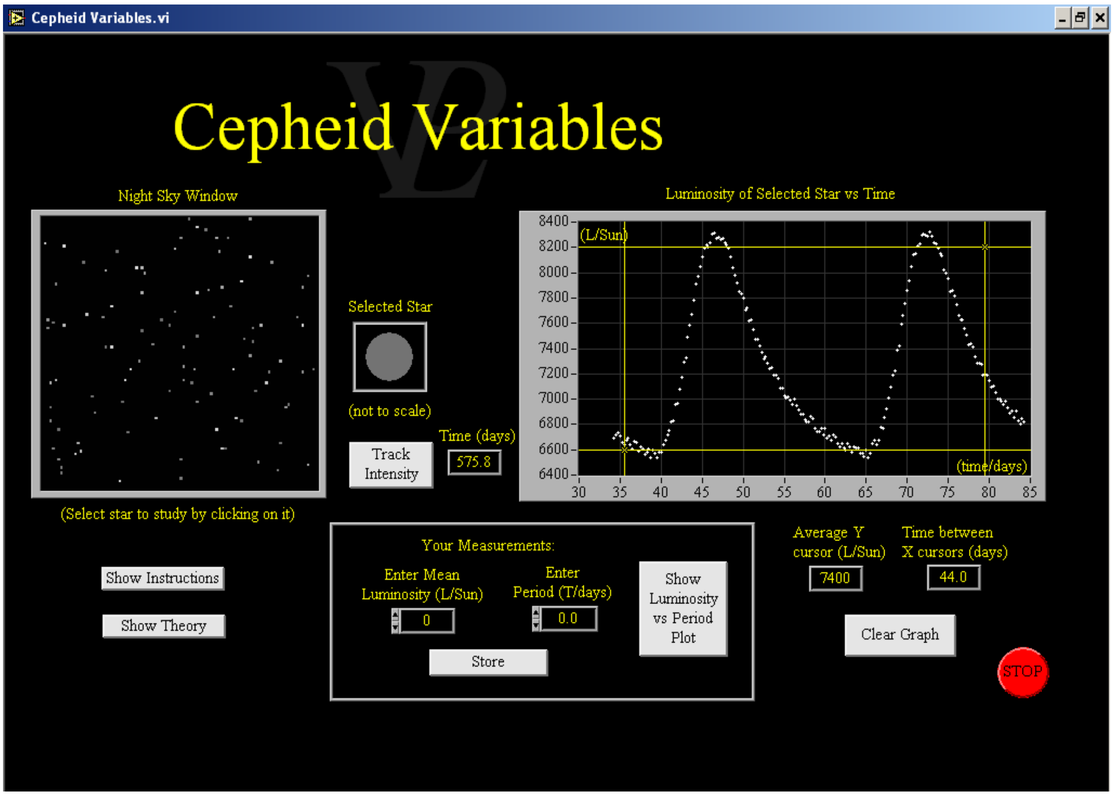
SIMULATIONS

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!

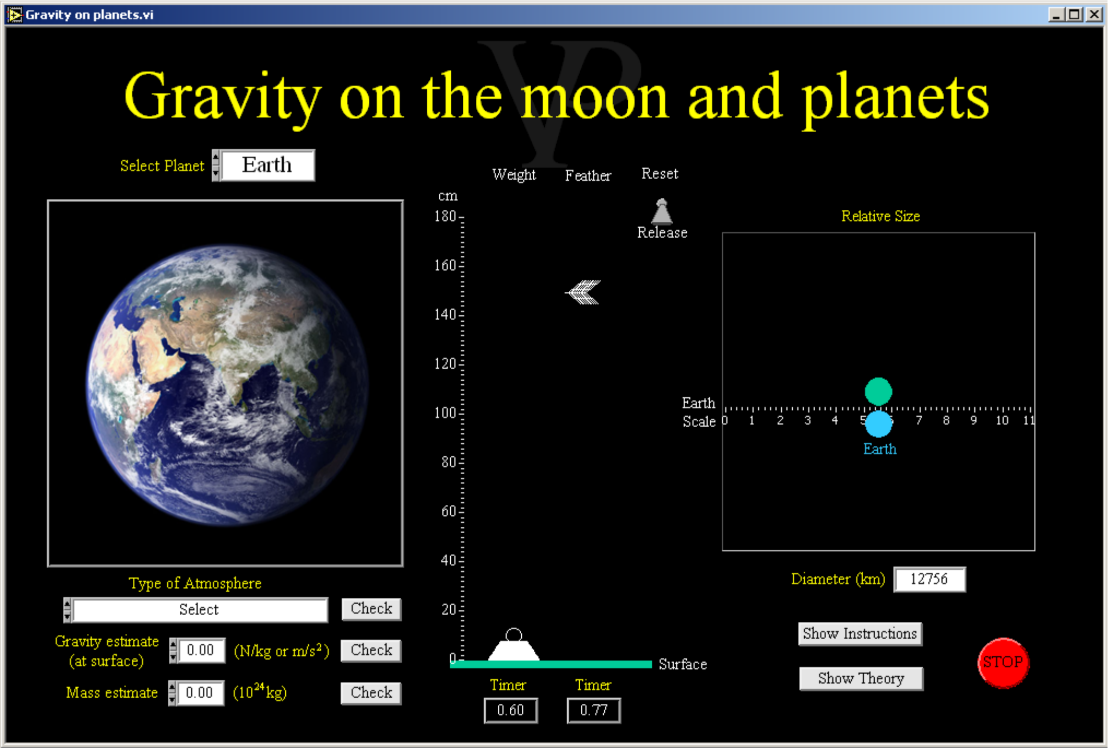
In order to do this study properly it was necessary to first determine the distance to the individual Cepheid stars using the parallax method. Once the distances have been determined it is then possible to convert the brightness measurements observed on Earth in to absolute Luminosity measurements.

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 x 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

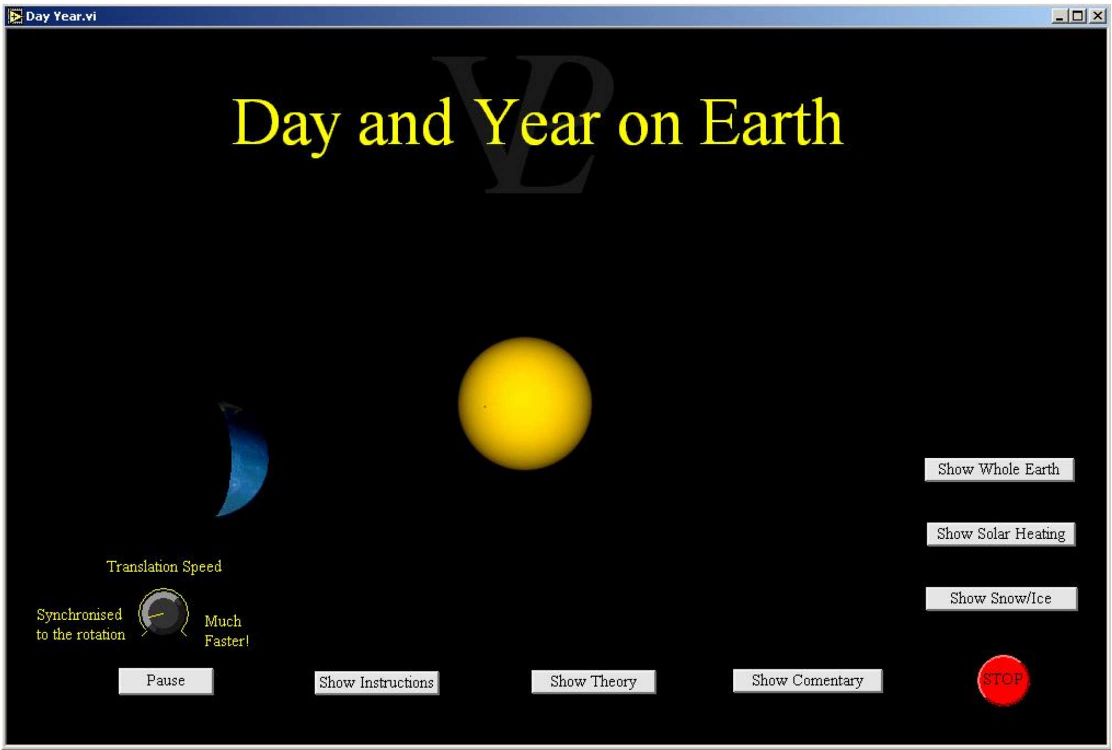
$g = (2 \times \text{fall}) / t^2$

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 $M = g\,R^2 / G$

1.3 Day Year **Basic/Advanced**

This simulation shows how the days and years are related to the rotation and translation of the Earth. It also shows the effect of the tilted axis of the Earth and how this gives rise t temperature variations and the seasons.

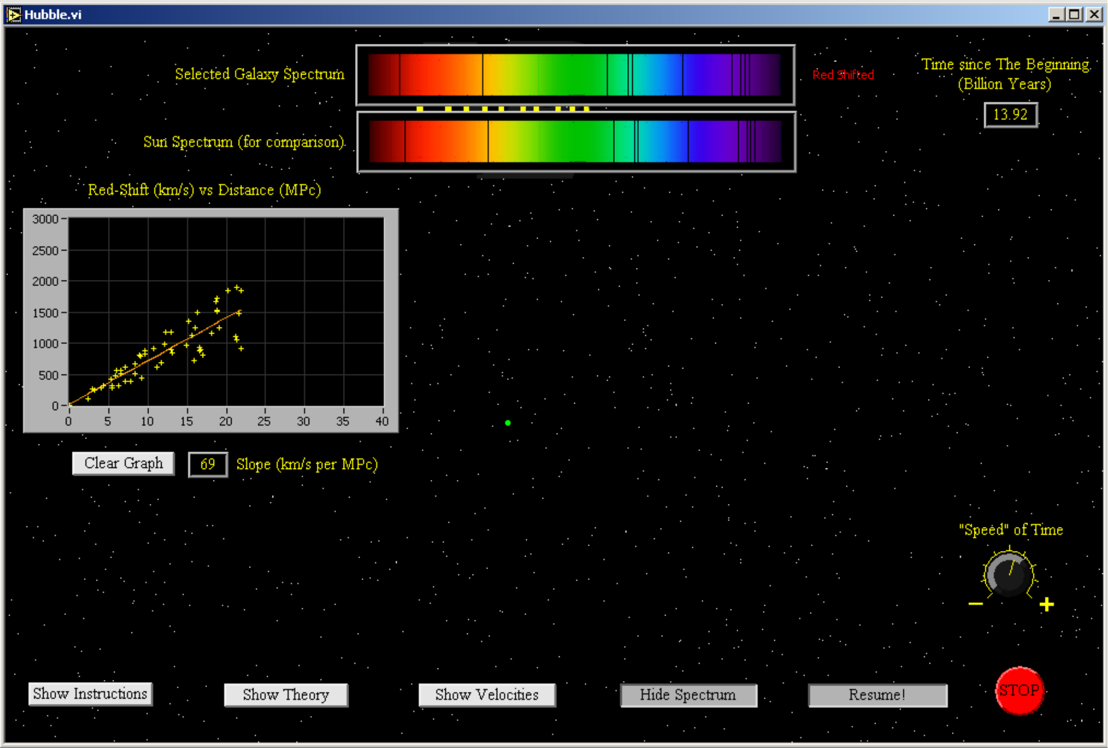


The movement of the Earth around its own axis, as well as around the Sun, and also the tilt of the Earths axis are interesting and important features of Creation which not only govern temperatures, climates and seasons, but also make life on Earth possible.
The time taken for the Earth to complete one rotation about its own axis is called a Day. If the Earth did not spin, or if it rotated too slowly one side would roast, and the other would freeze! If it rotated too fast, there would not be a sufficient difference between the temperatures of the day and the night to evaporate water during the day and release it as dew during the night.
One complete translation of the Earth as it orbits around the Sun is called a Year. The plane that this orbit marks out is called the Ecliptic. The axis of rotation of the Earth is tilted by 23.44 degrees with respect to the perpendicular to the Ecliptic.
Summer Solstice (mid summer's day) is when the axis of the Earth is inclined directly towards the Sun
Winter Solstice (mid winter's day) is when the axis of the Earth is inclined directly away from the Sun.
The Vernal and Autumnal Equinoxes are the days when the axis of the Earth is inclined in a direction which is parallel to its orbit (neither towards or away from the Sun). On these two days the number of sunlight hours and night hours are exactly the same.

If the axis of the Earth was not tilted the length of days and nights would be constant all year round and there would be no seasons. This would reduce the surface area of the Earth that could grow vegetation.

1.4 Hubble **Basic/Advanced**

This simulation enables the student to notice the expansion of this 'universe' by measuring the red shift in the spectra from distant galaxies. After sufficient measurements the student can obtain his own value for the Hubble constant.



Everything in the universe seems to be moving away from us! This does not mean that we are at the centre of the universe, we think that any observer located anywhere in the universe would notice the same thing: The universe is expanding.

Distances and speeds are impossible to measure directly; they need to be inferred from intensities and red-shifts respectively. More distant galaxies will appear less intense, and using an inverse square approximation it is possible to obtain a measure of their distance from us. Hubble used the intensity of Cepheid Variables (stars whose intensity is related to the period of fluctuation in their intensity) to determine distances. The velocity of the galaxy is obtained by looking at the red shift z, where $z = d\lambda/\lambda$. where λ is the wavelength.

Edwin Hubble measured around 50 different galaxies and noticed a correlation between the speed of recession and the distance of a galaxy. At the time, it was thought that the spectral shift was due to the Doppler effect, however further advances in relativity have given rise to the concept of a "cosmological shift" which is related to the expansion of the universe. At small values of red shift the velocity obtained using Doppler theory is close to that obtained from the Cosmological model.

From his data, Hubble obtained a relationship of around 500 km/s per MPc. Today's accepted value is closer to around 68 km/s per MPc.

Hubble's "Law" states that $V = Ho\ D$ where V is the velocity in km/s, Ho is Hubble's constant and D is the distance to the galaxy.

Hubble's law is one of the pieces of evidence leading scientists to believe in the "Big Bang" theory. It should be noted however, that Ho has not necessarily been constant over all time. It is simply the value of the slope of the graph today.