Introduction

The S283 Multimedia guide provides information about each of the S283 activities and is used to start other packages provided on the S283 DVDs.

On the left-hand side you will see a list of folders corresponding to topics such as ‘The Solar System and internal structure’ and ‘The giant planets’. Click once on a folder and information about it will be displayed in this box (you may need to scroll down to read all the text). The list of activities relating to a particular topic can be seen by opening the folder (by double-clicking on the topic or by clicking once on the ‘**+**’ sign). Information about a particular activity can be viewed by selecting (i.e. clicking once on) the activity title (or icon). To start a DVD-based activity, choose the appropriate topic from the left-hand side, then click the **Start** button. The list of activities will be updated as you install each of the DVDs.

More information can be found in the top menu bar under **Help**.

The Solar System and internal structure

There are three activities associated with this part of the course. You should consult the S283 website:

- for advice on when you should undertake each activity
- to download the notes and comments for each activity.

The three activities involve the use of spreadsheets. If you are unfamiliar with spreadsheets then you should read the relevant sections of *Using your computer* before starting the activities.

The activities are:

- ‘Variation in planetary radii with density’. In this activity you will be introduced to the process of producing a log-linear graph in a spreadsheet package.
- ‘Meteorites and Spidergrams’. In this activity you will use a spreadsheet to compare the geochemistry of terrestrial materials and meteorites.
- ‘Peridotite to basalt alchemy’. In this activity you will use a spreadsheet to compare the geochemistry of terrestrial and extraterrestrial basalts with peridotite, a rock that represents the composition of the Earth’s mantle.

When you click on **Start**, a folder on the DVD-ROM with the spreadsheet for this activity will open. For each activity there are four files in total:

Activity_name.sxc (a spreadsheet of raw data for use in StarOffice)
Activity_name.xls (a spreadsheet of raw data for use in Microsoft Excel)

Activity_name_answer.sxc (a completed spreadsheet for use in StarOffice)
Activity_name_answer.xls (a completed spreadsheet for use in Microsoft Excel)

Before starting these activities you should ensure that you have an appropriate spreadsheet package installed on your computer – see the *Using your computer* guide for more details. You should use the files appropriate to your software.

Variation in planetary radii with density

This activity introduces you to one use of computer spreadsheets for the analysis of scientific data: the production of charts and graphs. You have already used the 'traditional' approach for producing a graph of scientific data in Question 1.1, namely plotting the data on a piece of graph paper. However, it is increasingly rare for scientists to use a pen and paper approach to data analysis, especially with extremely large datasets such as those derived from geochemical analyses or space missions. In this activity, you will reproduce the graph you constructed for Question 1.1 using the same data. The relevant raw data from Appendix A, Tables A1, A2 and A3 have already been entered into a spreadsheet.

If you are already familiar with using spreadsheets you may be able to complete the activity in a shorter time than that suggested in the online study guide on the S283 website.

Study time: 30 minutes

Meteorites and spidergrams

‘Spidergrams’ are a powerful technique for comparing the pattern of element abundances between different samples because they can show all differences and similarities at a glance. This technique is particularly useful in helping to decipher the processes that have led to differentiation within terrestrial planets.

In this activity, you will analyse terrestrial geochemical data from the Earth’s crust and mantle and compare it with the composition of a ‘primitive’ meteorite (i.e. a CI carbonaceous chondrite). This comparison takes the form of an arithmetical calculation that produces a ratio, or quotient, for each element. The process of producing such a ratio for a range of elements in this manner is known as ‘chondrite normalization’ and, when these data are plotted on a suitable graph, the resulting pattern provides a powerful technique of determining the fate of different elements during the evolution of our planet.

Before starting this activity you should:

- have read to the end of Section 2.2.1 of *The Solar System*. In attempting Question 2.2 of Chapter 2 you will already have manually completed a comparable series of exercises.
- ensure that you have an appropriate spreadsheet package installed on your computer - see the *Using your computer* guide for more details.

If you are already familiar with using spreadsheets you may be able to complete the activity in a shorter time than that suggested.

Study time: 90 minutes

Peridotite to basalt alchemy

As you have already seen, ‘spidergrams’ are a powerful means of comparing the pattern of element abundances between different materials because they can show all differences and similarities at a glance. This technique can also be employed to reveal similarities and differences in the basalt lavas from the Moon and Mars, and is particularly useful in helping decipher the processes that have led to differentiation within these bodies.

In this activity, you will compare geochemical data of basalts from the Earth, Moon and Mars with the composition of Earth’s mantle (i.e. peridotite). This comparison takes the form of an arithmetical calculation that produces a ratio, or quotient, for every element of each basalt type. This is similar to the process employed for ‘chondrite normalization’ in the earlier ‘Meteorites and spidergrams’ activity, but with the difference that it is the composition of peridotite that will be used to ‘normalize’ the basalt data. Such data are then said to be ‘mantle normalized’ and can be plotted on a suitable graph. The resulting pattern provides another useful interpretative technique to the geochemical ‘toolkit’.

Before starting this activity you should:

- have read to the end of Section 3.1.4 of *The Solar System*. In attempting Question 3.2 you will already have qualitatively assessed similar data, and manually completed a comparable series of exercises.
- ensure that you have an appropriate spreadsheet package installed on your computer - see the *Using your computer* guide for more details.

If you are already familiar with using spreadsheets you may be able to complete the activity in a shorter time than that suggested.

Study time: 90 minutes

Planetary surface processes

There are three activities associated with this part of the course. You should consult the S283 website:

- for advice on when you should undertake each activity
- to download the notes and comments for each activity.

The activities are:

- 'The nature of impacts and their impact on nature'. A short (25 minute) video introducing several of the concepts covered in chapter 4.
- 'The crater calculator'. This activity will familiarize you with some of the parameters that affect crater size.
- 'The terrestrial cratering rate'. In this activity you will manipulate cratering data to derive a cratering rate for a planetary surface – in this case the Earth.

Additional resources:

- Image Archive resources relevant to this part of the course.

The nature of impacts and their impact on nature

This video programme is concerned with the impact of asteroids and comets with Earth and the effect that such impacts might have had on the Earth's environment. Most of the planets of the Solar System with rocky or icy surfaces show large numbers of impact craters. On earth, the evidence of impacts is harder to find since geological processes such as weathering and erosion soon destroy the surface expression of an impact crater. Because of this lack of direct evidence, geologists have often been reluctant to accept that impacts may have played a role in the geological or biological evolution of the Earth. To date, however, around 170 weathered impact craters have been identified on Earth. This programme examines the evidence for an impact at one of these: the Ries crater in southern Germany. You'll examine this evidence in greater detail as you study Chapter 4 of *The Solar System*.

Study time: 30 minutes

The crater calculator

This activity will familiarize you with some of the parameters that affect crater size. Using a computer programme that compares a variety of crater scaling laws for impactor versus crater sizes you will analyse how density and velocity of the impactor, angle of impact, and density of the target, affect crater size. You will plot the results from these analyses using spreadsheet software.

Note: for this activity we have not provided a spreadsheet of raw data, you have to generate that data yourself using the crater calculator program. The activity notes contain examples of the type of plots that you should aim to obtain.

Study time: 2 hours

The terrestrial cratering rate

In this activity you will become familiar with how to manipulate cratering data to derive a cratering rate for a planetary surface – in this case, the rate at which large craters are formed at the Earth's surface. The activity uses a website that lists actual crater statistics for the Earth: location, sizes, and constraints on age. These ages are never absolute: some have large or small error bars associated with them, and some indicate a 'greater than', or 'less than' age. The difficulty in establishing accurate ages for craters contributes a significant error in using cratered surfaces as chronometers. The site is updated on a regular basis as new data become available. In this activity you use the data contained in this site to demonstrate the basic principles involved in determining the ages of cratered surfaces.

Note: Since the data for this activity are continually updated, the spreadsheet that you will use is provided on the S283 website and not on the DVD-ROM. You should download that spreadsheet and its associated activity notes and comments from the website.

Study time: 90 minutes

Image Archive: volcanoes, dunes and craters on planetary surfaces

In addition to the images reproduced in *The Solar System*, the Image Archive contains many more images obtained by spacecraft of planetary surface processes. You can access these in two ways.

1. By clicking on the **Planets** button, then browsing each planetary body to view images.
2. By clicking on the **Planets** button, then clicking on **Keyword Search** and entering keywords to look for specific features.

Useful keywords for this section of the course include: volcano, volcanoes, volcanic, crater, impact, dune, dust, river, valley, water.

Note: You can abbreviate a keyword, so entering ‘volcan’ will search for all keywords beginning with those letters.

Click on the **Image Archive** button to launch the Image Archive.

Atmospheres of the terrestrial planets

There are no activities associated with this part of the course.

Additional resources:

- Image archive resources relevant to this part of the course.

Image Archive: atmospheres of the terrestrial planets

In addition to the images reproduced in *The Solar System*, the Image Archive contains many more images of the atmospheres of Venus, Earth and Mars. You can access these in two ways.

1. By clicking on the Planets button, then browsing each planet to view images.
2. By clicking on the Planets button, then clicking on Keyword Search and entering keywords to look for specific features.

Useful keywords for this section of the course are: **cloud**, **atmosphere**, **infrared**.

Click on the **Image Archive** button to launch the Image Archive.

The giant planets

There are two activities associated with this part of the course. You should consult the S283 website:

- for advice on when you should undertake each activity
- to download the notes and comments for each activity.

The activities are:

- Wind speed on Jupiter. This activity uses images of clouds on Jupiter to calculate wind velocity
- Interiors of the giant planets. This activity examines the interior structure of the giant planets.

Additional resources:

- Image Archive resources relevant to this part of the course.

Wind speed on Jupiter

In this exercise you will be calculating a wind velocity at a particular latitude on Jupiter by tracking the movement of a cloud. This is the method by which wind velocities on Jupiter, Saturn, Uranus and Neptune were obtained by Voyager and from later telescope observations. The only direct measurement of wind speed for these planets so far has come from the Galileo probe which sampled the atmosphere of Jupiter.
A NASA movie of Jupiter is provided and you will be asked to determine the position of the cloud initially and after a given time. From your measurements you can obtain the distance travelled by the cloud in the time given and hence the speed of the cloud relative to an observer (you) outside the planet. You will then convert this to a wind velocity as would be experienced by an observer in the planet. We use wind velocity here because you are determining not only the magnitude of the wind but also its direction – denoted by a positive or negative sign. Finally you will be asked to consider the sources of errors in such determinations.
You will find it useful to have read Book 1 Chapter 6 Section 6.3.3 before starting this exercise.

Study time: 1 hour

Interiors of giant planets

This activity is designed to give you some insight into why there is so much uncertainty surrounding the composition of the interiors of the giant planets. You will use a spreadsheet to explore the density of mixtures of rock and gas as a function of pressure. You will then compare your results with the variation of the density of a standard icy materials mixture with pressure.

Study time: 1 hour

Image Archive: the giant planets

In addition to the images reproduced in *The Solar System*, the Image Archive contains many more images of the giant planets and their satellites. You can access these in two ways.

1. By clicking on the Planets button, then browsing each planet to view images.
2. By clicking on the Planets button, then clicking on Keyword Search and entering keywords to look for specific features.

Click on the **Image Archive** button to launch the Image Archive.

Minor bodies of the Solar System

There are two activities associated with this part of the course. You should consult the S283 website:

- for advice on when you should undertake each activity
- to download the notes and comments for each activity.

The activities are:

- Kepler's laws. A computer program that allows to explore orbital parameters.
- Tidal heating. A short (12 minute) video that looks at tidal heating.

Additional resources:

- Image Archive resources relevant to this part of the course.

Kepler's laws

This activity will allow you to familiarize yourself with the parameters of an orbit, and to see Kepler's laws in action. You will be running a computer program where you can define an orbit, and then view a particle moving around that orbit. The program can also define two orbits, and run them simultaneously in order to simulate the effects of orbital resonance.

Study time: 1 hour

Tidal heating

One heat source known to be generated within planetary bodies is tidal heating, which is created by the distortion of shape resulting from mutual gravitational attraction between two planetary bodies. This short video looks at this process in more detail with the aid of animations.

Study time: 12 minutes

Image Archive: minor bodies

In addition to the images reproduced in *The Solar System*, the Image Archive contains many more images of the giant planets and their satellites. You can access these in two ways.

1. By clicking on the Planets button, then browsing each planet to view images.
2. By clicking on the Planets button, then clicking on Keyword Search and entering keywords to look for specific features.

Suitable keywords for the section of the course, would be the names of minor bodies, e.g. Gaspra, Ida, Phobos or browse the minor bodies section of the archive.

Click on the **Image Archive** button to launch the Image Archive.

Solar System origins and meteorites

There are no activities associated with this part of the course. However, you should consult the S283 website for late-breaking information about the course and for information on support materials that you may find useful in your studies. The website's address is http://courses.open.ac.uk/S283

Origin of life and the early Earth

There are five activities of varying length associated with this part of the course. You should consult the S283 website:

- for advice on when you should undertake each activity
- to download the notes and comments for each activity.

The activities are:

- Introduction to ISIS/Draw and WebLab ViewerLite
- Molecules activity
- Build your own genetic code
- Life and its origins quiz
- Planetary materials

Introduction to ISIS/Draw and WebLab ViewerLite

In this activity you will be introduced to two useful pieces of software that enable you to draw molecules and view them in three dimensions. Click the **Start** button to begin this activity.

Study time: 30 minutes

Molecules activity

While working through the first chapter of *Life in the Universe*, you have come across several types of molecules and examined their role in living systems. In this activity you will use Isis/Draw and WebLab ViewerLite to produce simple lipids, view them in three dimensions and identify their hydrophobic and hydrophilic ends. You will then load pre-drawn amino acids into WebLab ViewerLite and use the three dimensional view to determine whether they exhibit chirality. Finally, you will load a pre-drawn nucleotide into WebLab ViewerLite, identify its constituent parts and suggest the type of nucleic acid from which it is derived.

Click the **Start** button to open the folder containing the files you will need for this exercise.

Study time: 1 hour

Build your own genetic code

Nucleic acids are the largest macromolecules found in living systems and consist of a backbone of alternating sugar and phosphate units with additional nitrogen-containing ‘bases’ sticking out sideways from the sugars. The sequence of bases represents the genetic code. Bases on one strand of a nucleic acid can bond to bases on another. But only specific bases pair with each other and this is the key to replicating the genetic code.

In this activity you will build a nucleic acid (DNA) from its constituent units, replicate its genetic code and follow the first step (production of messenger RNA) in using it to synthesize proteins.

Study time: 1 hour

Life and its origins quiz

In this activity you will work through a series of multiple-choice questions which are based on key concepts relating to the origin of life. Click the **Start** button to begin this activity.

Study time: 15 minutes

Planetary materials

In this activity you will investigate the possible origins of three meteorite samples using geochemical data. In the first part you will construct a spidergram to examine the element abundances between the samples to help you reach a preliminary interpretation as to the origin of the samples. You will then study oxygen isotope data for the meteorites to further refine your initial interpretation before examining the astrobiological implications of organic molecules isolated from the meteorites.

Click the **Start** button to open the folder containing the files you will need for this exercise.

Study time: 90 minutes

The living Universe: Mars, Europa and Titan

There are three activities of varying length associated with this part of the course. You should consult the S283 website:

- for advice on when you should undertake each activity
- to download the notes and comments for each activity.

The activities are:

- Chaos on Europa
- Animation of the surface of Titan
- The Cassini/Huygens mission

Additional resources:

- Image Archive resources relevant to this part of the course.

Image Archive: Mars

In addition to the images reproduced in *Life in the Universe*, the Image Archive contains many more images of Mars. You can access these in two ways.

3. By clicking on the **Planets** button, then browsing the **Mars** section.
4. By clicking on the **Planets** button, then clicking on **Keyword Search** and entering keywords to look for specific features.

Useful combinations of keywords could include: Mars water, Mars dust, Mars polar.

Click on the **Image Archive** button to launch the Image Archive.

Chaos on Europa

You should perform this activity when you have reached the end of Section 4.2.3. Allow about three hours in total, of which about 50 minutes should be required for the final part (*Europa images on the internet*). You will need internet access at the start and again at the end of the activity.

Aims

This activity introduces you to reading, interpreting and commenting on an article or *paper* that was published in the professional scientific literature. It also gives you practice at using the internet to locate spacecraft images of specific targets.

Study time: 3 hours

Animation of the surface of Titan

This ‘film’ was made by combining a number of static images acquired with the Hubble Space Telescope’s Wide Field Planetary Camera at near-infrared wavelengths (between 0.85 microns and 1.05 microns) in October 1994. It is believed that at these wavelengths Titan’s haze is sufficiently transparent to allow direct mapping of the surface. The colours shown are ‘false colours’, representing the different amounts of infrared radiation from different regions. The prominent bright area corresponds to a region of enhanced emission. The polar regions could not be mapped due to the telescope’s viewing angle of the poles and the thick haze near the edge of the disk. These regions are therefore shown with a uniform colour. The resolution in these images corresponds to a distance on Titan’s surface of around 575 km.

The period of rotation of Titan is around 16 days, the same as its orbital period around Saturn. This means that the same face of Titan is always pointed towards Saturn (just as for the Earth and the Moon).

Just what the bright and dark regions correspond to isn’t known – they might represent continents, oceans, impact craters or other features.

Click the **Start** button to view this clip.

The Cassini/Huygens mission

The Cassini/Huygens mission is a tripartite collaboration between ESA (the European Space Agency), NASA (the US National Aeronautics and Space Administration) and ASI (the Italian Space Agency). Its target is the Saturnian system and it is the heaviest spacecraft ever to have been launched to the outer Solar System. The Cassini spacecraft will orbit Saturn for at least 4 years after arrival in 2004 while the Huygens Probe will land on the surface of Titan, Saturn’s largest satellite, in January 2005. The mission honours two astronomers who pioneered modern observations of Saturn.

The Titan Probe is named after Christiaan Huygens, who discovered Saturn’s largest satellite in 1655. The orbiter is named after Jean-Dominique Cassini who discovered the satellites Iapetus, Rhea, Dione and Tethys, as well as ring features such as the Cassini division, in the period 1671-1684.

In this folder you will find some animations showing a view of the spacecraft, the interplanetary trajectory which enables the spacecraft to reach Saturn and the descent of the Huygens Probe onto the surface of Titan.

The spacecraft

This animation shows the combined Cassini Orbiter spacecraft and the Huygens Titan Probe which represent the heaviest craft (5.82 tonnes at launch) ever to have been launched to the outer Solar System.

Some of Cassini's main features include the following:

- There are two identical main engines (for redundancy), used for spacecraft velocity and trajectory correction changes.
- There are also 16 monopropellant hydrazine thrusters arranged in four groups of four. The thruster engines are used for altitude control and also for small velocity-change manoeuvres.
- The spacecraft is 3-axis stabilized, meaning that its orientation in three orthogonal axes is controlled.
- Electrical power is derived from three Radioisotope Thermoelectric Generators (RTGs) onboard. In these RTGs, radiation emitted by Plutonium-238 is absorbed and generates heat. The heat generated by this natural process is converted into electricity by solid-state thermoelectric converters.

Communication with the Earth is affected via a 4 m-high gain antenna which also served to protect the spacecraft from the effects of solar radiation in the early part of the mission when Cassini was much closer to the Sun. Cassini also carries two smaller low gain antennae. Cassini carries 12 scientific instruments, located in various positions around the periphery of the spacecraft.

Click the **Start** button to view this animation.

The interplanetary trajectory

No existing launch vehicle could have sent the nearly 6 tonne Cassini/Huygens craft directly to Saturn. So mission designers used the technique called ‘gravity assist’, which has now been well tried and tested on a variety of space missions. Gravity assist works because of the mutual gravitational pull between a moving planet and a spacecraft. The planet, of course, pulls on the spacecraft. But the spacecraft's own mass also pulls on the planet. This permits an exchange of energy. This animation shows the complete trajectory from launch from Earth to arrival at Saturn.

After launch on 15 October 1997, Cassini/Huygens looped around the Sun twice. On the first loop it flew close behind Venus where it ‘stole’ some of the planet's orbital momentum on 26 April 1998. The next loop provided a second fly-by of Venus, on 24 June 1999, and one of Earth, on 18 August 1999. Given these three ‘gravity assist’ boosts, Cassini/Huygens finally had enough orbital momentum to reach the outer Solar System. One last gravity assist from Jupiter on 30 December 2000 gave Cassini/Huygens the final thrust of energy it needed to propel itself all the way to Saturn.

Once Cassini/Huygens reaches Saturn in July of 2004, the spacecraft will begin to fall towards the massive gas giant. At just the right moment, Cassini will fire its main rocket engine for about 95 minutes to slow down. Instead of simply whizzing by, the spacecraft will become forever trapped in orbit, like one of Saturn's moons. The Huygens Probe will separate from the Cassini orbiter and descend into Titan's murky atmosphere, while the orbiter examines Saturn and its retinue of satellites as it repeatedly loops around the planet.

Note that this animation and commentary was produced before the spacecraft’s launch in 1997.

Arrival at Saturn and Titan

You will view a simulation of the arrival of Cassini/Huygens at Saturn, the deployment of the Huygens Probe and its descent onto the surface of Titan. Arrival at Saturn takes place in July 2004 with arrival at Titan in January 2005. The nature of the surface of Titan as shown has been interpreted with a degree of 'artistic licence', since to date even whether the surface is solid or liquid has not been confirmed!

Note that this animation was prepared before the successful launch of Cassini/Huygens in October 1997. Click the **Start** button to view this animation.

The Huygens Probe

The Huygens Probe is the European Space Agency’s main contribution to the joint Cassini/Huygens mission. Riding piggyback on the Cassini Saturn orbiter (provided by NASA), it will be delivered to Titan to make ‘one off’ measurements during its descent through Titan’s atmosphere and possibly for a few minutes on its surface.

The probe carries a complement of 6 scientific experiments to effect these measurements. The probe’s front shield has a diameter of 2.7 m and serves to slow the probe down by aerodynamic drag at the top of Titan’s atmosphere. Power is provided by 5 $LiSO_2$ batteries that provide a total energy of 1800 watt-hours.

Once the probe is released from Cassini, some 3 weeks before it arrives at Titan, *it is completely autonomous*. This means that there is no communication to Huygens from the Earth or from Cassini. All decisions and control functions must be generated exclusively by the onboard systems. The prime industrial contractor for the Huygens Probe is Alcatel (France).

Descent Imager and Spectral Radiometer

The Descent Imager and Spectral Radiometer (DISR) is a very sophisticated camera system which simultaneously views upwards, downwards and sideways from the Huygens Probe, at wavelengths through the visible part of the spectrum and into the near infrared. You will see an interview with the DISR Principal Investigator who describes some of the instrument capabilities and speculates as to what 'landscapes' it may discover on the surface of Titan.

Click the **Start** button to view this video.

Gas Chromatograph and Mass Spectrometer

You will view an animation that shows schematically the molecular constituents of Titan's atmosphere (dominated by N_2 and CH_4). When irradiated by ultraviolet radiation from the Sun, they undergo a series of photochemical reactions, resulting in the production of increasingly complex long-chain molecules. The atmospheric gases are analysed by an instrument on Huygens called the Gas Chromatograph and Mass Spectrometer (GCMS). The operation of the GCMS is shown schematically. Samples of the atmosphere are forced into the instruments by dynamic pressure. The sample is then ionized and passed to a separate chamber for analysis.

Click the **Start** button to view this animation.

Aerosol Collector and Pyrolyser

The Aerosol Collector and Pyrolyser (ACP) is designed to collect and analyse aerosol particles from Titan's atmosphere. In the animation, you can see a demonstration of how this instrument works. Two separate samples are collected, first over the altitude range 150 km to 45 km and then from 30 km to 15 km. This instrument operates in conjunction with the GCMS.

Click the **Start** button to view this animation.

Doppler Wind Experiment

This video clip shows an interview with the Principal Investigator of the Doppler Wind Experiment (DWE). Uniquely of the 6 Huygens experiments, it consists of hardware on both the Huygens Probe (a radio transmitter) and on the Cassini Orbiter (a receiver). The experiment consists of measuring the frequency of the radio signal transmitted by the Huygens Probe as received by the Cassini Orbiter. By using the well-known Doppler effect, the relative velocity between the 2 craft can be determined. This information can then be used, along with other data, to determine the speed and direction of any winds encountered during the probe's descent through Titan's atmosphere.

Click the **Start** button to view this video.

Surface Science Package

The Surface Science Package (SSP) is a collection of 9 independent sensors designed to measure a whole range of physical properties of the atmosphere and surface. Some sensors are optimized for a liquid surface, others for a solid surface. The SSP Principal Investigator discusses certain aspects of the instrument and you will view an animation of the operation of two of these.

Click the **Start** button to view this video.

Huygens Atmospheric Structure Instrument

The Huygens Atmospheric Structure Instrument (HASI) comprises a set of sensors to investigate the physical and electrical properties of Titan's atmosphere, including temperature, pressure and density as a function of altitude. Wind gusts and, in the event of landing on a liquid surface, wave motion, will also be detected. HASI also carries a simple microphone to sense acoustic noise from sources such as thunder, rain or wind.

The living Universe: Exoplanets

There are three activities of varying length associated with this part of the course. You should consult the S283 website:

- for advice on when you should undertake each activity
- to download the notes and comments for each activity.

The activities are:

- Micro-lensing
- Doppler spectroscopy
- Simulations of planetary migration.

Micro-lensing

In this activity you will be able to re-create light curves that arise from the gravitational lensing of a background star by a foreground star–planet lens. By configuring the geometry and properties of the star and planet you can assess for yourself the chances of discovering a planet by micro-lensing. The activity also shows you the lensed image for these events – a luxury which even the best telescopes cannot provide to astronomers at present.

Before starting this activity you should read Chapter 6 of S283 Book 2.

Study time: 1 hour

Doppler spectroscopy

This activity offers a non-mathematical approach to understanding the most successful planet-hunting method to date. You will be guided through the main principles of Doppler spectroscopy using a 3D simulation of between one and three planets orbiting a star. You can then investigate how the various parameters (star mass, planet mass, semimajor axes, eccentricities and orbit orientation) lead to different radial velocity time profiles. At the end of the activity you will be given the opportunity to experiment freely with the simulation so that, for example, you can re-create the radial velocities profiles of real planetary systems.

Before starting this activity you should read Chapter 6 of S283 Book 2.

Study time: 2 hours

Simulations of planetary migration

This activity is intended to help you visualize planetary migration. It is based on a series of short animations derived from state-of-the-art calculations of the interaction of a growing planet with its circumstellar disc of gas.

Study time: about 20 minutes

SETI, the Search for Extraterrestrial Intelligence

There are no activities associated with this part of the course. However, you should consult the S283 website for late-breaking information about the course and for information on support materials that you may find useful in your studies. The website address is http://courses.open.ac.uk/s283.

Background science

This section contains topics from *Background Science* and educational software programs that may be of use in revising some of the important scientific concepts that are required for S282 *Astronomy* or S283 *Planetary Science and the Search for Life.*

Note that the programs are supplied as an *additional resource*: they are to help provide background information that some students might need before studying specific topics in S282 or S283. Guidance on when it might be appropriate to study these packages will be given on the respective course websites.

Most of these software packages were originally developed for the Level 1 course S103 *Discovering Science*.

Introduction to Background Science

This section provides an introduction to the background science topics for use in S283.

Press the **Start** button to open the introduction.

Topic 1 Physical Quantities

This topic includes units and the manipulation of units.

Press the **Start** button to open this topic.

Topic 2 Motion, Force and Energy

This topic on motion, force and energy includes Newton's laws.

Press the **Start** button to open this topic.

Topic 3 Waves and Radiation

This topic includes waves, electromagnetic radiation and photons.

Press the **Start** button to open this topic.

Topic 4 Matter

This topic includes states of matter (i.e. solids liquids and gases), temperature and pressure, atoms and their constituents, chemical compounds, and nuclear reactions.

Press the **Start** button to open this topic.

Topic 5 Rocks and Minerals

This topic includes the basic characteristics of rocks and minerals.

Press the **Start** button to open this topic.

Topic 6 Mathematics

The topics covered in this section include powers and logarithms, precision, algebra and equations, proportionality, circles, angles, trigonometry and graphs.

Press the **Start** button to open this topic.

Topic 7 Useful tables and data

This topic includes the Periodic Table, the Greek alphabet, selected physical constants and unit conversions.

Press the **Start** button to open this topic.

Electrons in atoms

In this activity, you will investigate the quantum world of atoms. You will compare and contrast the energy level diagrams, spectra and electron probability clouds of the hydrogen atom, the helium ion He^+ and the lithium ion Li^{2+}. Your task is to investigate how these properties depend on the atomic number *Z* of the atom or ion.

Study time: 30 minutes

Nucleons in nuclei

In this activity, you will investigate the quantum world of nuclei. You will look at which nuclei exist, and of those, which are stable, which are unstable, and how the unstable ones decay. The activity includes a database of the properties of all the possible nuclei in the Universe. Learning how to navigate around this database is an important skill that you will develop here.

You will also carry out some simulated experiments involving unstable nuclei, which will enable you to discover the law of radioactive decay.

Study time: 90 minutes

Quarks

In this activity, you will investigate the quantum world of quarks. You will see that reactions involving quarks are of two types, known as strong interactions and weak interactions. Using a ‘virtual particle accelerator’ you will discover the rules underlying such interactions, and then using a ‘quark fruit machine’ you will build hadrons from quarks, again following a few simple quantum rules.

Study time: 30 minutes

Balancing equations

This activity gives you practice at balancing chemical equations. Note: The final set of equations is rather difficult.

Study time: 30 minutes

Surveying the Periodic Table

This activity consists of seven sections. One of them is an introduction in which you will see how the Periodic Table can be broken down into four smaller blocks of elements. In four other sections, you are given the chance to visit each of these blocks in turn, and at each stage, you will find videos, photographs and information. Another section shows you how the blocks fit together to produce a periodicity in the distribution of metals, semi-metals and non-metals that extends over the whole table. Finally, there is a section which derives a widely recommended form of the Periodic Table.

Study time: 1 hour

Chemical periodicity and electron structure

This activity is concerned with the link between the electron configurations of atoms and the Periodic Table. You will see how the correct procedure for writing electron configurations, and the use of electron structure to explain chemical periodicity, can be developed together in a mutually supportive way.

There are five sections. Sections 1 and 2 deal with the labelling of the sub-shells of electrons, and their capacities. In Section 3, you move through the Periodic Table, allocating electrons to the sub-shells of atoms. In Sections 4 and 5, you will write electron configurations for atoms from different parts of the Periodic Table and outer electron configurations for atoms of the typical elements.

Study time: 40 minutes

Chemical equilibrium

This activity introduces you to chemical equilibrium at the molecular level and then asks you to explore how changing reaction conditions lead to changes in the mixture of chemicals present at equilibrium.

There are four sections. In the first, you will observe the behaviour of molecules in chemical equilibrium for a chemical reaction between gases. In the next two sections, you will develop an understanding of how yields of reactions can be changed by adjusting the pressure and temperature. The last section deals with chemical equilibrium for reactions in solution, and you will use your observations to find a relationship between concentrations in an equilibrium mixture.

Study time: 1 hour

Rocks digital kit

This package provides a digital kit of specimens of some of the common rock types referred to in S283. You should look at it in conjunction with the section on rocks and minerals in the *Background science* booklet. Note: You need to have the Adobe Acrobat reader software installed on your machine to run this package.

Click the **Start** button to run this package.

eBooks

The course books are provided in electronic form as eBooks. These can be viewed using the Adobe Acrobat software that is provided with the course (see the *Using your computer* guide).

The eBooks can be used:

- with ‘screen reader’ software, i.e. software that can read the text aloud
- for searching for a particular word or phrase

The Solar System - Part 1

The Solar System considers the incredible diversity of our own Solar System that has been made accessible by planetary missions.

Part 1 of the book starts by examining the layout of the Solar System before discussing the internal structure and surface processes of the terrestrial planets.

Press the **Start** button to open the eBook.

The Solar System - Part 2

The Solar System considers the incredible diversity of our own Solar System that has been made accessible by planetary missions.

Part 2 of the book examines the giant planets, minor bodies of the Solar System, Solar System origins and meteorites.

Press the **Start** button to open the eBook.

Life in the Universe - Part 1

Life in the Universe introduces the science of astrobiology, which deals with the origins of life on Earth and elsewhere in the Universe.

Part 1 of the book examines the origin of the building blocks of life on Earth, how these simple biogenic compounds could have combined to create life and how life affects and is affected by the environment from which it arose.

Press the **Start** button to open Part 1 of the eBook.

Life in the Universe - Part 2

Life in the Universe introduces the science of astrobiology, which deals with the origins of life on Earth and elsewhere in the Universe.

Part 2 of the book examines whether and how life could exist elsewhere in the Universe and how we might go about detecting it if it does.

Part 2 of the eBook can be downloaded from the course website.