DAY AND NIGHT, SEASONS

Students model the motion of a planet around a star and investigate how day and night and seasons may be different on other planets.

Apparatus and Materials

(per group of 2 to 4 students)

- Lamp (one with an opal globe light bulb is ideal)
- Polystyrene balls of assorted sizes
- Bamboo barbecue skewers (with a length of approximately 30 cm)
- Marker Pen

Each student will also require a photocopy of the instructions and worksheet (pages 20 and 21 respectively).

Health & Safety and Technical Notes

Tell students not to stare directly into the lamp.

Learning objectives

After completing this activity, students should be able to:

- explain how day and night relate to planetary rotation.
- explain how seasons relate to the tilt of a planet's axis.
- describe how day and night and seasons may be different on different planets.
- discuss how life may adapt to differing conditions of light and temperature on exoplanets.

Introducing the activity

This activity extends a conventional treatment of day and night and seasons by asking students to apply their understanding to how exoplanets may differ from Earth. Introduce the idea of an exoplanet if this is unfamiliar to students. Explain that several thousand have now been observed and that astronomers seek to compare them to the familiar planets of the solar system. In particular, they would like to know if any might be home to life, and if any might even have advanced life forms comparable to humans.

Explain that astronomers can determine the radius of an exoplanet's orbit around its star (by timing its transit) and also determine whether its orbit is circular or an elongated ellipse.

The practical activity

Explain that a lamp represents a star and a polystyrene ball represents an exoplanet in orbit around it. Briefly remind students of why we experience day and night and seasons.

Students have to push a skewer through a ball to represent the exoplanet's axis. (You might want to do this for them in advance.)

They should mark the poles and the equator as reference points.

Working in pairs or small groups, students demonstrate night and day and seasons to each other. Encourage them to describe what an observer on the exoplanet would notice in terms of movement of the star in the sky, light intensity and temperature.

They should then go on to model the two types of exoplanet described on their worksheet and discuss them in the same terms as above. They should consider the possibilities for life in these alien worlds. ('Life' could mean human-like creatures, or organisms like bacteria which are more capable of living in a range of habitats.)

They could present their findings either in the form of an illustrated written report, or as a presentation to the class.

About exoplanetary orbits

On their worksheets student are asked to consider seasons and day and night on two exoplanets.

1: An exoplanet that orbits with the same face to its star at all times.

This type of planet is similar to the way in which we always see the same face of the Moon, and the exoplanet is described as 'tidally locked' to its star. Such planets rotate slowly. The time it takes to complete a rotation about its axis is equal to the time it takes to complete an orbit. Its day is as long as its year. Whether the planet experiences any seasonal variations or day-night cycles depends on the tilt of the planets axis. You may choose to limit the discussion to the simplest case of no axial tilt (see figure 5a).

Tidally locked planets are usually close to their stars and so the star will look big in the sky compared to how we see the Sun. The side of the exoplanet facing the star will always be in daylight and will always be hot. The back of the exoplanet, facing away from the star, will be in permanent darkness and hence cold. There will be a twilight zone between these two regions which might be a suitable place for life. Alternatively, life might exist beneath the surface. For planets with an axial tilt life may only be able to survive if it migrates back and forth between cooler and hotter regions throughout its year-long day.

2: A planet with an eccentric orbit.

Planets move in elliptical orbits, with the star at one focus. You could introduce this concept using two pins and a string to generate an ellipse (see **www.iop.org /exoplanets**).

Most of the planets in the Solar system have a low orbital eccentricity and move in an almost circular path. The Earth's distance from the Sun varies by only about 1% during the course of a year. This contributes in only a small way to seasonal variations. Our seasons come about because of the tilt of the Earth's axis.

An exoplanet with a more eccentric orbit will experience seasons differently: summer when it is closest to its star, winter when it is furthest away (see figure 5b). Note that the whole exoplanet will experience the same season at any time, however, if it is tilted the northern and southern hemisphere temperatures at any given latitude will still vary.

An eccentric orbit may take the exoplanet in and out of the 'habitable zone' (where conditions for life are thought to be most favourable) in the course of a year. Life might evolve to hibernate for part of the year, or to aestivate when the temperature is too high. Organisms would require energy stores to keep them going through these times.

Taking it further

Students can research the range of conditions where life is found on Earth. In particular, they could find out about extremophiles, organisms which live in extreme conditions of darkness, temperature, pressure and chemical environment. They could consider whether this makes it more likely that life exists elsewhere in the universe and what signs we might look for in the search for life on exoplanets.

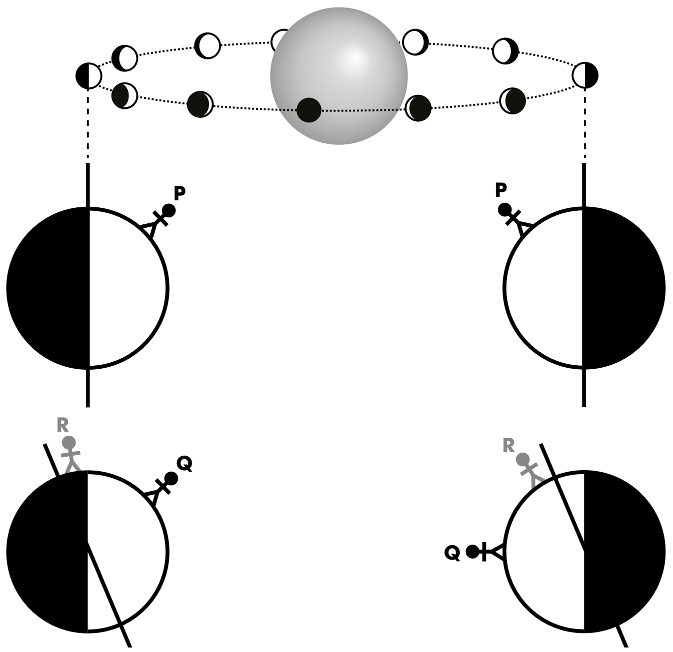

Figure 5b – A planet with an eccentric orbit

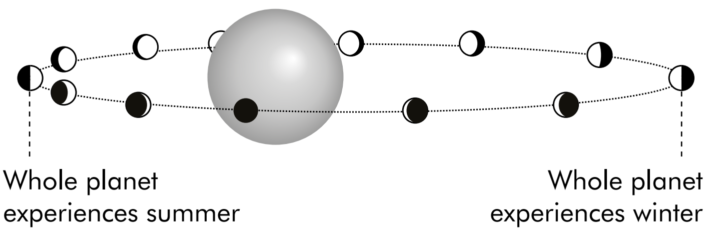

Figure 5a – An exoplanet that orbits with the same face to its star at all times.

(i) No Axial tilt The simplest case for a tidally locked planet is one with no axial tilt. For such a planet the star will always appear at the same point in the sky and the point on the planetary surface closest to the star will be hottest with the star directly overhead. No part of the planetary surface (e.g. P) will experience day-night or seasonal cycles.

(ii) With Axial tilt For an exoplanet with a tilted axis the star would move vertically in the sky as the planet orbited (but not across the sky) and there will be some temperature variation throughout its year-long 'day.' Whether there will be a day-night cycle will depend on latitude. For positions on the planetary surface such as Q the star will never set and nightfall will never occur. For positions such as R night will fall for some part of the cycle.