PLANET DENSITY

Students use iron and sand to model the composition of the Earth and estimate what fraction of the Earth is occupied by its iron core.

Apparatus and Materials

(per group of 2 to 4 students)

- Balance
- Measuring cylinder
- Steal ball bearing or steel block approx.. 2 or 3 cm across
- Sand

Each student will also require a photocopy of the instructions and worksheet (pages 16 and 17 respectively).

Health & Safety and Technical Notes

If using ball bearings, remind students that if any fall on the floor they must be picked up promptly so that so no-one slips on them. Give each group a dish to keep them in. A little bit of tissue paper on the balance will stop them rolling off.

Learning objectives

After completing this activity, students should be able to:

- measure mass and volume.
- calculate density from mass and volume.
- understand that planets can be classified according to their densities.

Introducing the activity

Introduce the idea of an exoplanet and explain why they are difficult to observe. (They are very distant and much smaller than stars, and they are not sources of light.)

Explain that astronomers can determine the radius and mass of an exoplanet, and hence deduce its density. By comparing an exoplanet's size and density with that of the Earth and other planets, they hope to find Earth-like planets orbiting other stars.

Explain that the Earth is made of two materials: the dense iron core and the less dense outer rocky region (mantle and crust). Its average density is between the densities of iron and rock. They are going to use a simplified model to estimate what fraction of the Earth is iron (by volume).

The practical activity

You could introduce the activity by showing a steel ball (to represent the Earth's core) and some Plasticine. Discuss their different densities. Explain how to calculate density and introduce units. (For ease of calculation g/cm^3 rather than kg/m^3 are used throughout this activity).

Wrap a layer of Plasticine around the ball to represent the mantle and crust. What can be said about the average density? (It must be between that of steel – 7.9 g/cm^3 and that of Plasticine – 1.9 g/cm^3.)

(You could measure mass and volume of the ball + Plasticine by immersing the ball in water in a measuring cylinder on a balance and then add increasing amounts of Plasticine. However, sand is a better material to represent rock as its density is closer to that of the rock found on the Earth's surface.)

A blank table for tabulating results and calculations is provided on the worksheet. Alternatively students can use a Microsoft Excel spreadsheet for processing data. Remind them that before taking readings for the sand-steel mixture they should place the measuring cylinder on the balance and zero it.

They should find that the average density decreases from that of steel as more sand is added. Typical results are shown in figure 4a. The equation for calculating the steel-percentage by volume is provided on the worksheet and a graph of density against percentage provides a straight line from which the percentage that gives a density of 5.5 g/cm^3 can be read (see figure 4b). They should get an answer of between 50-60%.

After the activity you may want to discuss the composition of the Earth (figure 4c). Explain that although the crust is of a similar density to sand, the rock in the mantle has a higher density (between 3 and 6 g/cm^3). What does this imply about the size of the core? Will it be bigger or smaller than their estimate? (They should conclude that their estimate provides a maximum size for the core; the actual volume will be lower). There is also the additional complication that the iron in the core is denser than the steel they have used in their model.

IOP Institute of Physics

About planetary densities

For the Solar System, the masses of planets can be deduced from the orbital speeds of their moons – a moon orbiting a massive planet has to orbit quickly to avoid being pulled in by its strong gravity. Their radii can be measured from photographs taken using telescopes, or by observing them transiting across distant stars.

The chart on the student instructions shows how we can divide them into the higher density rocky planets and the lower density gas giants. (The gases are, of course, frozen.) Astronomers would like to find examples of Earth-like exoplanets. They can then concentrate their efforts on trying to discover whether they may have signs of life such as atmospheres containing oxygen and methane.

It is harder to find the mass and radius of an exoplanet. The radius can be found from the transit light curve – the initial dip takes longer for a bigger exoplanet (see teacher notes for activity 1). The mass can be found from the wobble of the parent star as the exoplanet orbits it – the star moves in a small circle and this can be detected from the Doppler shift in its light.

Taking it further

Students can research the densities of some known exoplanets and identify ones that have similar densities to Earth.

Figure 4a – Typical results

	A	B	C	D	E	F
1	**Volume of steel (cm^3)**	**Total mass (g)** (sand + steel)	**Volume of sand (cm^3)**	**Total volume (cm^3)** (sand + steel)	**Steel percentage by Volume**	**Average density (g/cm^3)**
2	*7.6*	*60.1*	*0*	*7.6*	*100 %*	*7.9*
3		*87.6*	*11*	*18.6*	*41 %*	*4.7*
4		*110.1*	*20*	*28.6*	*27 %*	*3.9*
5		*130.1*	*28*	*35.6*	*21 %*	*3.7*
6		*160.1*	*40*	*47.6*	*16 %*	*3.4*
7		*182.6*	*49*	*56.6*	*13 %*	*3.2*

Figure 4b – Average density against steel percentage. The percentage that gives a density equal to that of the Earth (5.5 g/cm³) can be read from the graph.

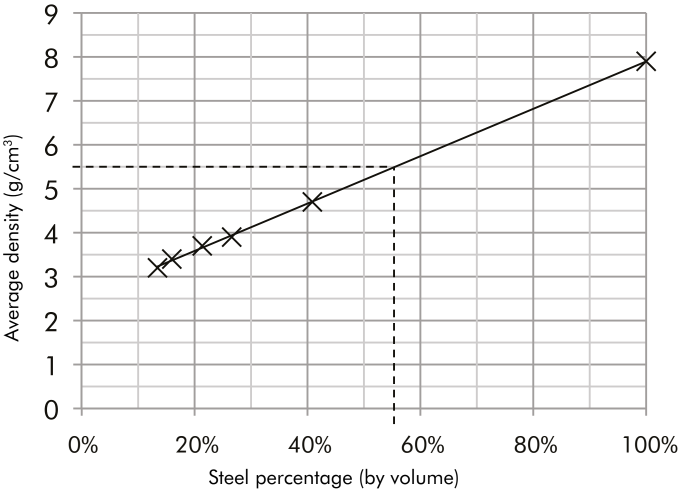

Figure 4c – Layers of the Earth, their approximate densities and composition. Density depends on depth as well as composition. For example, the iron core's density increases from around 10 g/cm³ (at its outer edge) to around 13 g/cm³ (at its centre).