TUTORIAL 3

Class Assignment

1 Am I on another planet?

1.1 Weighing scales

The planets, asteroids and comets in our Solar system have different physical characteristics such as their size and mass. The goal of this exercise is to calculate and compare your weight at the surface of these objects. First, there are some basic concepts and definitions to consider:

1. The **mass** of an object is the amount of matter contained inside an object. The mass of an object is an intrinsic property and is independent of where it is located in the Universe.

2. Gravity is an attractive, fundamental force of nature between material objects that have a mass. The strength of the **gravitational force** depends on the mass of the objects and the distance between them. For spherical objects like planets and moons, this would be the distance between their centres. The gravitational force between an object with mass m and another object with mass M, separated by a distance r is given by the simple formula:

   $\mathrm{F}_g = G \times m \times M/r^2$ where G is the gravitational constant (G=6.67×10^{-11} [$\mathrm{m^3kg^{-1}s^{-2}}$]).

3. Newton's second law states that *"A gravitational force* F_g *applied to an object with mass* m *causes it to accelerate"* according to the formula: $\mathrm{F}_g = m \times g$ with g the **gravitational acceleration** in units of [$\mathrm{m\ s^{-2}}$]. At the surface of the Earth, the gravitational force results in an acceleration of $a_g = 9.8$ [m s^{-2}] or 35 [$\mathrm{km\ hr^{-1}s^{-1}}$], meaning that every second an object is falling from a tower, its speed increases by 35 [$\mathrm{km\ hr^{-1}}$]. Note that the acceleration with which an object falls is independent on its mass m because $a_g = \mathrm{F}_g/m = G \times M/r^2$. On the Moon, where there is no atmosphere, a feather falls as quickly as a hammer.

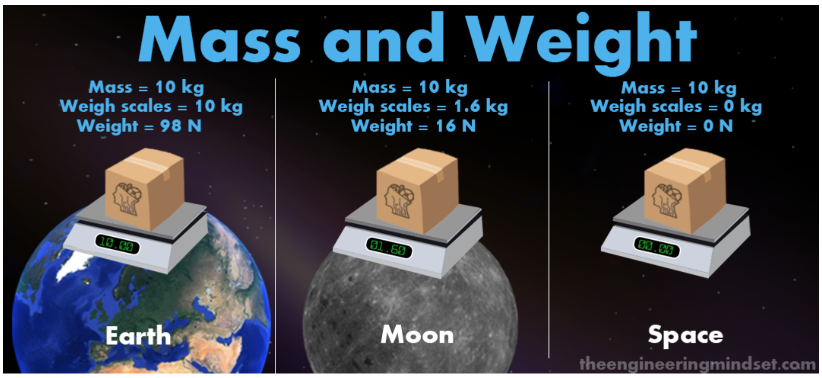

Figure 1: The difference between Mass and Weight.

4. The **weight** W of an object with mass m on the surface of a planet with mass M depends on the gravitational force F_g that acts upon it, according to $W = m \times a_g$. The unit of weight is not kilogram but *Newton* [N]. Therefore, the weight of an object with a mass m=10 [kg] at the surface of the Earth is $W = 10 \times 9.8 = 98$ [N].

$$\textbf{Weight} = \textbf{Mass x Gravitational acceleration} = m \times a_g = F_g$$

For example, on the surface of Mars, the gravitational acceleration a_g due to the mass M of the planet is less than on the surface of the Earth. This implies that an object's weight would be lower on Mars than it would be on Earth. However, it would still have the same amount of mass as on Mars as on Earth.
You've probably seen video footage of astronauts walking on the Moon. They seem to float between each step. At the surface of the Moon, the gravitational acceleration a_g and force F_g have about 1/6 the value compared to Earth. Therefore, astronauts on the Moon can lift more massive objects, jump higher and fall more slowly. So, if you went to the Moon, you would weigh less than you do here on Earth, even though your mass would be the same.

In the following exercise you will calculate the gravitational acceleration a_g and your weight W on the surface of different objects in our Solar system. Imagine you would dive into a pool and your dive would last 1 second, calculate the velocity in [km hr^{-1}] at which you would enter the water.

Table 1: Properties of objects in our Solar system.

Object	Mass 10^{24}[kg]	Radius [km]	Orbital period [years]	a_g [m s^{-2}]	Velocity [km hr^{-1}]	Weight [N]	Age [years]
Earth	5.97	6,378	1	9.8	35		
Moon	0.073	1,738	1				
Mars	0.642	3,396	1.88				
Ceres	0.00015	473	4.60				
Comet 67P	9.98×10^{-12}	1.5	6.44				
Jupiter	1898	71,492	11.9				
Uranus	86.8	25,559	84				
Pluto	0.0146	1,185	249				
Sun	1.99×10^{6}	347,850	-				-

1.2 I'm so young!

A year on Earth consists of 365.24 days. However, every planet has a different orbital period around the Sun. If you were born on another planet, you would technically have the same age as you do now, but your calculations would differ. Given in the table above are the different orbital periods for different objects. They have been scaled to the Earth's orbital period of 1 year. Just divide your age by these values given above, and see how old you are on different planets!

2 A tour of some Exoplanets

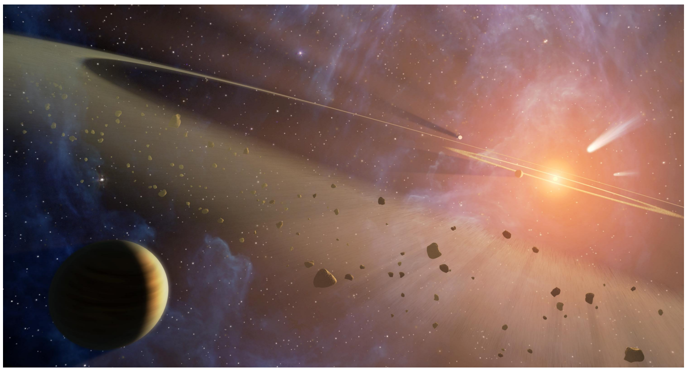

Figure 2: An artist's impression of exoplanets

Exoplanets are planets that lie beyond our solar system. The search for exoplanets has been ongoing for many decades, and thousands have been discovered with the help of different space telescopes, like Hubble and Kepler.

These exoplanets can be very different from the planets in our solar system, varying in size, orbits and physical features. The parent stars around which these exoplanets orbit also range in size and mass: Some are comparable to our Sun, while others are much more massive and/or brighter. The primary motivation behind the search for exoplanets has been the possible discovery of Earth-like planets, which orbit Sun-like stars and lie in the so-called habitable zones, implying that they could harbor life. These habitable zones are the range of orbits of a planet that can support the existence of liquid water which is critical for life. However, planets can be terrestrial or gaseous, and a variety of factors decide whether or not they can support life apart from their orbits.

With the help of the NASA simulation '*Eyes on the Solar System*', we will investigate a few of the discovered exoplanets in some detail.

1. Start by initializing the program, and then click on the option '*Eyes on Exoplanets*'
2. Explore different planetary systems and choose any 5 of them.
3. The left panel on the screen gives information for each exo-planet. Use this information to complete Table 2. *Note: The information that has been asked in the table is not available for all planets in the simulation.*

Exoplanet name	***Planet Type***	***How far from***	***Mass of central star w.r.t Sun***	***Which planet in SS can it be compared to in terms of***	***Habitable zone? Yes/No***	***Possibility of life forming on the planet?***	***Comments Why life can/cannot form Eccentricity of orbit--- Seasons? Other factors***
		Earth: **Central star:**		**Size** **Position**			
		Earth: **Central star:**		**Size** **Position**			
		Earth: **Central star:**		**Size** **Position**			
		Earth: **Central star:**		**Size** **Position**			
		Earth: **Central star:**		**Size** **Position**			
		Earth: **Central star:**		**Size** **Position**			

3 Telescopes

A telescope is an instrument that aids in the observation of remote objects by collecting electromagnetic radiation. The first telescope was invented in the 1600s in the Netherlands by Hans Lippershey. It was an optical telescope made using glass lenses. There are two main categories of optical telescopes:

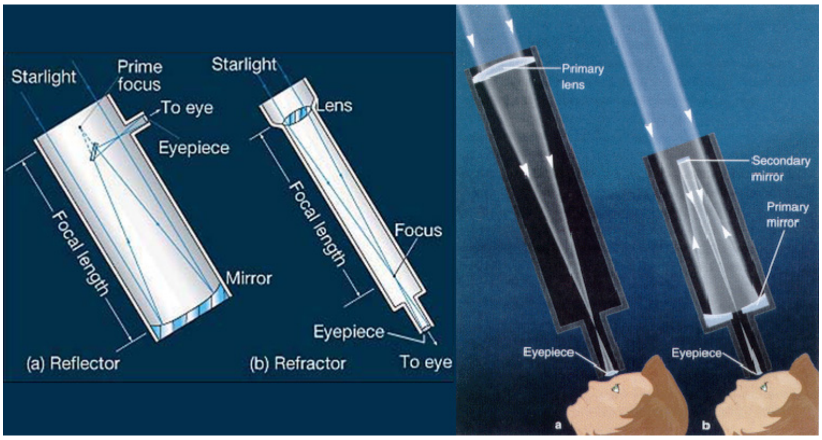

Figure 3: Difference between a reflector and a refractor

1. *Refracting telescopes*: An assembly of lenses is used to produce a magnified image.

2. *Reflecting telescope*: An assembly of mirrors is used to produce a magnified image.

Certain general terms are associated with each of the above types of optical telescopes. These terms are described below:

Objective: This is the primary mirror or the lens that collects and focuses light from a distant object. It creates an image near its focal plane.

Eyepiece: The eyepiece magnifies the image created by the objective. This magnified image is then observed using a camera or the eye.

Magnification: The amount by which the telescope can magnify a distant object. It depends on the focal lengths of the objective and eyepiece. The formula to calculate magnification is given by:

$$Magnification = \frac{focal\ length\ of\ objective}{focal\ length\ of\ eyepiece}$$

Light gathering power: The objective of any kind of telescope collects the photons coming from a distant cosmic source. A larger objective collects more photons and thus, the light gathering power (LGP) depends on the diameter of the objective of a telescope. The LGP is often compared to the LGP of the pupil of a human eye. The formula for this is:

$$Light\ Gathering\ Power = \left(\frac{diameter\ of\ objective}{diameter\ of\ pupil}\right)^2$$

Angular resolution: The minimum angular distance between distinguishable features in an image produced by the telescope. The angular resolution of an optical telescope in space, above the turbulent atmosphere, depends upon the diameter of the objective.

Field-of-View: The angular extent of the sky that can be seen through the telescope. This property depends inversely on the magnification of the telescope. This inverse relation will be demonstrated by means of the telescope simulation below.

Guidelines:

1) Go to the site http://astro.unl.edu/classaction/animations/telescopes/telescope10.html . You will see a model of a refracting telescope in which you can change the diameters and focal lengths of the objective and eyepiece. You also see a field of view in which you can choose to observe one of the three given targets: the Moon, Saturn or a star cluster.

2) You can also see three white boxes. The first one (top left) gives you the adjustments for the sizes of the aperture lens (objective lens), the eyepiece and the selection of the targets. The smaller box next to this is the focus adjustment slider. With this, you can adjust the focus for a given combination of the two lenses such that the object in your field of view becomes sharp. The third box (bottom left) gives you information on the readout parameters. With this, you can note the change in the Light Gathering Power, angular resolution, magnification and field of view of the telescope as you change the size of the two lenses.

Instructions and questions:

A. For each combination of objective diameter and focal length of the eyepiece, note the LGP, resolution, magnification and Field-of-View of the telescope in the tables provided below. Vary the focus such that you get a sharp image.

Table 2: The Light Gathering Power for different combinations of objective diameter and focal length of the eyepiece

LGP	8-inch	6-inch	4-inch
40 mm			
20 mm			
10 mm			

Table 3: The angular resolution for different combinations of objective diameter and focal length of the eyepiece

Resolution	8-inch	6-inch	4-inch
40 mm			
20 mm			
10 mm			

Table 4: The magnification for different combinations of objective diameter and focal length of the eyepiece

Magnification	8-inch	6-inch	4-inch
40 mm			
20 mm			
10 mm			

Table 5: The Field-of-View for different combinations of objective diameter and focal length of the eyepiece

Field-of-View	8-inch	6-inch	4-inch
40 mm			
20 mm			
10 mm			

B. Note down the telescope configuration for questions a and b., and answer the questions c and d.:

1a. The largest LGP ________________________
1b. The smallest LGP ________________________
1c. For a given objective diameter, does the LGP change for different eyepieces?
1d. For a given eyepiece, does the LGP change for different objective diameters?

2a. The largest resolution ________________________
2b. The smallest resolution ________________________
2c. For a given objective diameter, does the resolution change for different eyepieces?
2d. For a given eyepiece, does the resolution change for different objective diameters?

3a. The largest magnification ________________________
3b. The smallest magnification ________________________
3c. For a given objective diameter, does the magnification change for different eyepieces?
3d. For a given eyepiece, does the magnification change for different objective diameters?

4a. The largest field of view ________________________
4b. The smallest field of view ________________________
4c. For a given objective diameter, does the Field-of-View change for different eyepieces?
4d. For a given eyepiece, does the Field-of-View change for different objective diameters?

C. If you change the target from the Moon to Saturn or to the star cluster, what do you observe for different objective diameters? What do you think is the reason for the different observations?