# **Astro 101** *Useful Physics Notes*

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## Spring/Fall Semesters

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Important **physics** from Chapter 3:

1. The primary job of a telescope is to collect a large amount of light and bring it to a focus. The amount of light depends on the area of the primary mirror (or lens). As mirrors (or lenses) have the same geometrical shape as a disk the area of a mirror (or lens) is given by:

   $$Area \;=\; \pi r^2 \;=\; \pi(\frac{d}{2})^2$$

   where $r$ is the radius, and $d$ is the diameter of the mirror (or lens).

2. The *resolving power* of a telescope is it's ability to distinguish the images of two stars (or other points of light) with almost zero angular separation (on the celestial sphere). Curiously physics and the wave nature of light limits our ability to do this job! The physics of this is called *diffraction*: see 3-1 more precisely on page 82 of the text. As the two images have almost zero angular separation, it is reasonable that we should <u>minimize</u> the *diffraction* angular size of the images, given by:

   $$angular\ size \;=\; \frac{0.25''\lambda}{d} \;\propto\; \frac{\lambda}{d}$$

   where $\lambda$ is the wavelength of the light being imaged in microns ($\mu$m) and $d$ is the diameter of the primary mirror (or lens) in meters $m$. Recall that visible light has a wavelength of about 500 nanometers (which is the same as 1/2 micron). Thus for visible light and a telescope with a 1m primary the *angular size* is about $0.125''$ which is much smaller than the typical $1''$ image size resulting from atmospheric *seeing*: see Fig 3.13 on page 83 of the text.

   In contrast to telescopes working in the visible, radio telescopes image light with wavelength of about 5 cm (see inside front cover of the text). This is about 100,000 times larger than the wavelength of visible light! Thus for comparable resolving power radio telescopes need *effective* diameters of about 100,000 m (*i.e.* 100km)! This *effective* diameter is possible using interferometry where $d$ is no longer the diameter of a given radio telescope but is instead the maximum physical separation of the radio telescopes.

Important **physics** from Chapter 4:

Table 4.1, on page 106 of the text, lists a number of properties of solar system objects: the orbit size given as the semi-major axis (in A.U.), the orbit period (in Earth years), the object mass (in Earth masses), the radius of the object (in Earth radii) and the average density of the object (in $kg/m^3$). I summarize below what these quantities are are and how they are obtained.

1. Object *Orbit period*:

   The orbit period, $P$, is the time it takes the object, *e.g.* a planet, to make one complete orbit of the Sun in Earth years. This is our starting point as this is what astronomers can measure most accurately.

2. Object *Orbit semi-major axis*:

   For all objects orbiting the Sun, the orbit periods, $P$, and semi-major axis values, $a$, are related by Kepler's third law: $P^2 = a^3$. If/when we need the semi-major values in standard units, *e.g.* meters, or kilometers, then we measure the Astronomical Unit, A.U., as shown in Figure 1.14 page 36 of the text to obtain 1 A.U. $\equiv 1.5 \times 10^8$km: see Appendix 3 of text.

3. Object *Mass*:

   Recall that the *mass*, of an object is a measure of the total amount of matter contained within the object. Your weight, $w$, and mass, $m$, are simply related: $w = mg$ where $g$ is the acceleration of gravity. Thus to measure your mass we use your weight and the know value for $g$ to measure your mass. Unfortunately we can not do this for *e.g.* the planets!

   To measure the mass of any astronomical body we use the orbit parameters of any satellite orbiting the body. Thus we use the Moon to measure the mass of the Earth. Similarly we use the Earth (or any other object orbiting the Sun) to measure the mass of the Sun. Then the mass, $M$, of the object is given by:

   $$M = \frac{rv^2}{G}$$

   where $r$ is the radius of the satellite's orbit in meters, $v$ is the velocity (speed) of the satellite in meters/second, and $G$ is Newton's gravitational constant, see Figure 1.18 page 39 of the text. Fret not: astronomers can determine the velocity of the satellite knowing the radius of the satellite orbit and the time for the satellite to orbit the object in seconds.

   OK this is way too extreme!! Please do not be concerned: you will not be required to use this *formula*. My point is only to emphasize that once the orbit parameters of a satellite of an object are known, then we (*i.e.* astronomers) can evaluate the mass of the object!

4. Object *radius*:

   Once the orbit parameters of the Earth and any other object are known, astronomers can determine the actual *distance* to the object (from the Earth) in *e.g.* meters at any give time. So at what time? Simple: the time when someone (astronomer) made a measurement of the angular size of the "object". By angular size we mean the *angular diameter* of the object in degrees, see 4-1 more precisely on page 105 of the text. Then the physical *diameter* of the object is related to the *distance* to the object and the observed *angular diameter* by:

$$diameter(m) \;=\; distance(m) \times \frac{angular\ diameter(degrees)}{57.3^\circ}$$

Finally the radius, $r$, of the object is then simply:

$$r \;=\; diameter/2$$

Again do not be concerned: you will not be required to use this *formula*. My point is only to show the rather simple steps to determine the properties of astronomical objects and specifically the quantities summarized in Table 4.1.

5. Object *density*:

   Astronomical objects come in vast range of sizes. Thus how can one look for common features if we are comparing object that differ in size by huge factors? One answer is to compare the *density* of objects, where *density* is the ratio of the object's mass, $M$, and *volume*:

$$density \;=\; M/volume$$

   Our standard units for mass is kilograms, $kg$, and volume is cubic meters, $m^3$, thus the unit for density is $kg/m^3$.

   For spherical objects the volume is related to the radius, $r$, of the object: $volume = (\frac{4\pi}{3})r^3$. Thus once we have measured the object mass, point 3 above, and radius, point 4 above, we know (*i.e.* can calculate) it's density!

   IF you are interested to compare the density of various planets or moons to something common you might compare to water with density $1000kg/m^3$. Suddenly objects are not so different!