

Chapter 3

26) *Earth is closer to the Sun in January than in July. Therefore, in accord with Kepler's second law,*

b) Earth travels faster in orbit around in January than in July. Kepler's second law states that planets sweep out equal areas in equal time. The Earth is closer to the Sun in January than in July therefore, the Earth must travel in its orbit more quickly in January than July to sweep the same area in the same amount of time (See figure 3.18).

46) *You are an astronomer on the planet Tirth, which orbits a distant star. It has recently been accepted that Tirth is spherical in shape, though no one knows its size. One day, you learn that on the equinox your sun is directly overhead in the city of Tyene, located 400 kilometers due north of you. On the equinox, you go outside and observe that the altitude of your sun is 86° . What is the circumference of Tirth.*

The method of Eratosthenes is given in the Special Topic portion of page 63 and it can be used to solve this problem. The angular distance between yourself and the city of Tyene, since you are due south of Tyene, is the difference in the Sun's altitude at the two locations on a given day. In Tyene the Sun is directly overhead thus, has an altitude of 90° (i.e. 90° with respect to the horizon). The Sun's altitude on the same day at your location is 86° , therefore the angular separation is 4° . Since a full circle is 360° you know that the angular separation between you and Tyene is $1/90$ th of a full circle ($4/360 = 1/90$). Multiplying the distance between you and Tyene (400 km) by 90 (i.e. building a circle out of 4° segments) the circumference of the planet Tirth is estimated to be 36,000 km.

48) *The recently discovered Eris, which is slightly larger than Pluto, orbits the Sun every 557 years. What is its average distance (semimajor axis) from the Sun? How does its average compare to that of Pluto?*

Using Kepler's third law the orbital period (P) is related to the semimajor axis (a) by $P^2 = a^3$. Therefore, $a = P^{2/3}$ where a is in units of Astronomical Units (AU) and P is in units of years. Plugging 557 years (the orbital period of Eris) into the previous expression gives 67.7 AU as semimajor axis of Eris, which is the same as the average distance. Looking up the average distance to Pluto in Table E.2 gives a distance of 39.5 AU. Therefore, the distance of Eris with respect to Pluto is 1.7 (67.7 AU/39.5 AU). This means Eris is approximately one and a half times farther from the Sun than Pluto.

Chapter 4

32) *If the Earth were twice as far from the Sun, the force of gravity attracting Earth to the Sun would be*

c) one quarter as strong. Looking at the gravitational force equation given in Section 4.4 on page 123 the force of gravity (F_g) equals the gravitational constant (G) times the mass of object one (M_1) times the mass of object two (M_2) divided by the distance (d) squared. In the question it asks for what the force of gravity would be if the Earth were twice as far from the Sun ($2D_E$, where D_E is the distance to Earth). The mass of the Sun (M_S), mass of the Earth (M_E), and the gravitational constant will all be the same for when the Earth is twice as far from the Sun, therefore taking the ratio of the force of gravity at twice the current distance (F_2) with respect to the gravitational force at its current distance (F_1)

from the Sun will only be dependent on distance (i.e. $F_2/F_1 = \frac{GM_S M_E / (2D_E)^2}{GM_S M_E / (D_E)^2}$). Therefore, $F_2/F_1 = \left(\frac{D_E}{2D_E}\right)^2 (1/4) = (1/4)$. The gravitational force from the Sun at twice the distance from Earth is one quarter of the gravitational force Earth feels at its current distance.

48) *We can calculate the kinetic energy of any moving object with a very simple formula: kinetic energy = $\frac{1}{2}mv^2$ where m is the object's mass and v is its velocity or speed. Table 4.1 shows that metabolizing a candy bar releases about 10^6 joules. How fast must the candy bar travel to have the same 10^6 joules in the form of kinetic energy? Is your answer faster or slower than you expected?*

Plugging in the kinetic energy (KE) of 10^6 joules into the kinetic energy equation one is able to solve for v assuming a candy bar mass of .2 kilograms. Rearranging the terms to get velocity by itself, $v = \sqrt{2(KE)/m}$. The units of joule are kilogram times meter squared divided by seconds squared (kg [m/s]^2). The kinetic energy, which has units of joules, is divided by mass, which has units of kilograms, therefore, the kilogram units will cancel out. This leave the units of meters square divided by seconds squared under the square root. Taking the square root of the units the right hand side of the equation has units of meters per second. Velocity is distance over time, therefore also has units of meters per second. Doing unit analysis like this is useful to make sure that you have solved the problem correctly. Plugging in the numbers the velocity for a candy bar to reach 10^6 joules of kinetic energy is 3162 meters per second [m/s]. This means the candy bar would have to go a little under a two miles per second to have its kinetic energy equal its metabolic energy.

54) *Calculate the acceleration of gravity of the surface of each of the following worlds. How much would you weigh, in pounds, on each of these worlds? a. Mars b. Venus c. Jupiter d. Jupiter's moon Europa e. Mar's moon Phobos*

The easiest thing to do is keep everything is Earth units since we know the acceleration due to gravity on Earth is 9.8 m/s². The gravitational acceleration on any planetary body (a_P) is related to the acceleration on Earth (a_E) by $a_P/a_E = (M_P/R_P^2)/(M_E/R_E^2)$. If you convert all your masses to Earth masses and radii to Earth radii calculating the gravitational acceleration on a planetary body is just $a_P = a_E (M_P/R_P^2)$.

Since the force you apply due to gravity is your weight $W_E = m \times a_E$ where m is your mass and is constant, the ratio of the of gravitation acceleration on a planet compared to that on Earth (i.e. $a_P/a_E = [W_P/m]/[W_E/m]$) gives your weight on any heavenly body (W_P) by $a_P/a_E \times W_E = W_P$. This ratio is nice because you can use pounds directly without having to convert it to Newtons, which in my case is 215 lbs. Finally, we just need to plug in the numbers.

a $a_P/a_E = 0.39$; $a_P = 3.8 \text{ m/s}^2$; $W_P = 83.9 \text{ lbs}$

b $a_P/a_E = 0.91$; $a_P = 8.9 \text{ m/s}^2$; $W_P = 196 \text{ lbs}$

c $a_P/a_E = 2.53$; $a_P = 24.8 \text{ m/s}^2$; $W_P = 544 \text{ lbs}$

d $a_P/a_E = 0.13$; $a_P = 1.25 \text{ m/s}^2$; $W_P = 28.0 \text{ lbs}$

e It is best to convert Phobos mass ($1.84 \times 10^{-9} M_E$) and radius ($1.88 \times 10^{-3} R_E$) into Earth units. Then you get $a_P/a_E = 5.19 \times 10^{-4}$; $a_P = 5.1 \times 10^{-3} \text{ m/s}^2$; $W_P = .11 \text{ lbs}$

Chapter 5

28) *Blue light has higher frequency than red light. Thus, blue light has*
a) higher energy and shorter wavelength than red light. The energy of a photon of light is related to its frequency by simply multiplying the frequency by Planck's constant, therefore as frequency increases so does energy. Recall that frequency times wavelength equals speed. This makes sense from unit analysis. Wavelength has a unit of distance and frequency has a unit of inverse time, so by multiplying frequency and wavelength you arrive at something that has units of distance per time (i.e speed). The speed of light is constant (in a vacuum) so to get the wavelength of light all one needs to do is divide the speed of light by frequency ($\lambda = c/\nu$). Blue light having a higher frequency than red light means the speed light divided by frequency is smaller for blue light than red (i.e. a shorter wavelength)