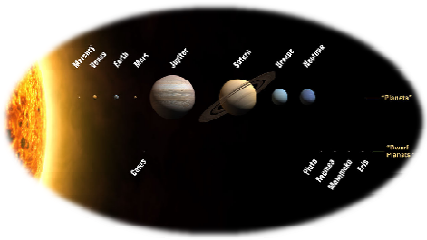
SPH4U UNIVERSITY PHYSICS

ELECTRIC, GRAVITATIONAL, & ... FIELDS

- Orbits
  (P.297-303)

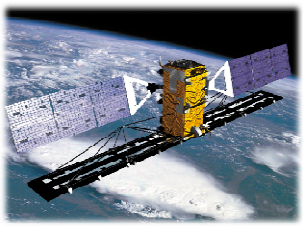
Satellites

*A **satellite** is an object or a body that revolves around another body that usually has much more mass than the satellite. For example, the planets are natural satellites of the Sun and the planetary moons are natural satellites of the planets.*



Satellites

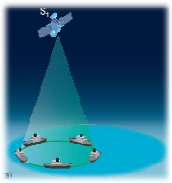
***Artificial satellites**, on the other hand, are human-made objects that orbit Earth or other bodies in the solar system. RADARSAT-1 and RADARSAT-2 as well as the International Space Station (ISS) are examples of artificial satellites.*



Satellites

Another well-known example of artificial satellites is the network of 24 satellites that make up the Global Positioning System (GPS).

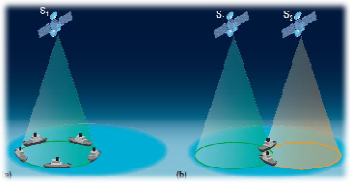
(a) The data from one satellite will show that the object is somewhere along the circumference of the circle.



Satellites

Another well-known example of artificial satellites is the network of 24 satellites that make up the Global Positioning System (GPS).

(b) Two satellites consulted simultaneously will refine the location to one of two intersection spots.



Satellites

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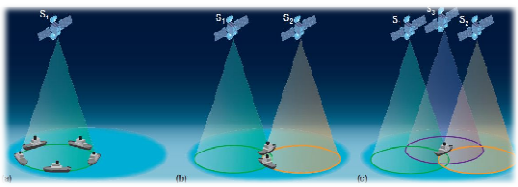
(c) With three satellites, the intersection of the three circles will give the location of the object to within 15 m of its actual position.



Satellites

SATELLITE

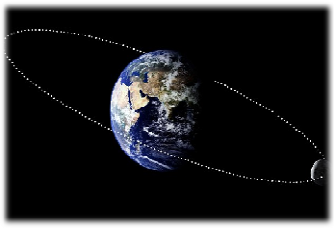
- object or body that revolves around another body due to gravitational attraction

ARTIFICIAL SATELLITE

- satellite that is man-made

Satellites in Circular Orbits

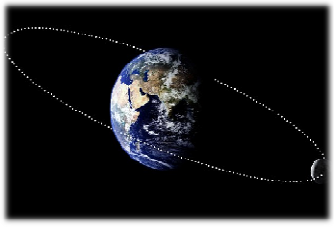
When Newton developed the idea of universal gravitation, he also theorized that the same force that pulls objects to Earth also keeps the Moon in its orbit. One difference, of course, is that the Moon does not hit the Earth's surface. The Moon orbits Earth at a distance from Earth's centre – called the ***orbital radius****.*



Satellites in Circular Orbits

NOTE!

The Moon's orbit, similar to the orbits of the planets around the Sun, is actually elliptical. However, for most problem-solving purposes, we can closely approximate the orbits by assuming that they are circular.



Satellites in Circular Orbits

As such, to analyze the motion of a satellite in uniform circular motion about Earth:

$$F_c = F_g$$
$$ma_c = mg$$
$$\frac{v^2}{r} = \frac{Gm_E}{r^2}$$
$$v = \sqrt{\frac{Gm_E}{r}}$$

NOTE!

This equation holds for any orbiting body in a central gravitational field. If a satellite orbits around any other large body with mass m, we can replace the mass of Earth in the equation and generalize it.

Satellites in Circular Orbits

ORBITAL SPEED

- the speed needed by a satellite to remain in orbit

$$v_{orbit} = \sqrt{\frac{Gm_p}{r}}$$

where v is the orbital speed of the satellite (m/s)
G is the universal gravitational constant (6.67×10^{-11} N·m^2/kg^2)
m_p is the mass of the object about which the satellite orbits (kg)
r is the orbital radius (m)

Satellites in Circular Orbits

PRACTICE

1. Determine the speeds of Venus and Earth as they orbit the Sun. Venus has an orbital radius of 1.08×10^{11} m while Earth has an orbital radius of 1.49×10^{11} m. The mass of the Sun is 1.99×10^{30} kg.

$v_V = 3.51 \times 10^4$ m/s
$v_E = 2.98 \times 10^4$ m/s

Satellites in Circular Orbits

PRACTICE

2. Material has been observed in a circular orbit around a black hole some five thousand light-years away from Earth. Spectroscopic analysis of the material indicates that it is orbiting with a speed of 3.1 x 10^7 m/s. If the radius of the orbit is 9.8 x 10^5 m, determine the mass of the black hole, assuming the matter being observed moves in a circular orbit around it.

   m_{BH} = 1.41 x 10^{31} kg

Satellites in Circular Orbits

PRACTICE

3. What is the difference between a geosynchronous orbit and a geostationary orbit?

   a geosynchronous orbit is an orbit around Earth of a satellite with an orbital speed that matches Earth's rate of rotation – to an observer on Earth, the satellite will appear to travel through the same point in the sky every 24 h

   a geostationary orbit is a type of geosynchronous orbit in which the satellite orbits directly over the equator – to an observer on Earth, the satellite would appear to remain fixed in the same point in the sky at all times

Satellites in Circular Orbits

PRACTICE

4. The International Space Station orbits Earth at an altitude of ~ 350 km above Earth's surface. If the mass of the Earth is ~ 5.98 x 10^{24} kg and the radius of Earth is ~ 6.38 x 10^6 m, determine the speed needed by the ISS to maintain its orbit.
   (Hint: $r_{ISS} = r_{Earth} + r_{altitude}$)

   v = 7700 m/s

✔ Check Your Learning

TEXTBOOK

P.303 Q.6,7,9

P.307 Q.1-4 (PJ: General Relativity) ☞ *you will need to read!*