Physics 161
Lecture 10, Summary
Universal Gravitation

October 5, 2017

Lecture 10: learning objectives

This lecture

You will be able to apply Newton's law of gravitation to calculate gravitational forces and the gravitational potential energy.

You will be able to calculate the escape speed.

You will be able to state Kepler's three laws and apply the third law to determine the motion of orbiting bodies.

Newton's universal gravitation

Newton's law of universal gravitation:
Two objects attract each other with a force that is proportional to the product of their masses and inversely proportional to their separation.

$$F_{grav} = G\frac{m_1 m_2}{r^2}$$

Here the gravitational constant is
$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$.

The gravitational potential energy at large distances is given by:

$$E_{\mathrm{P}} = -G\frac{Mm}{r}$$

Escape speed

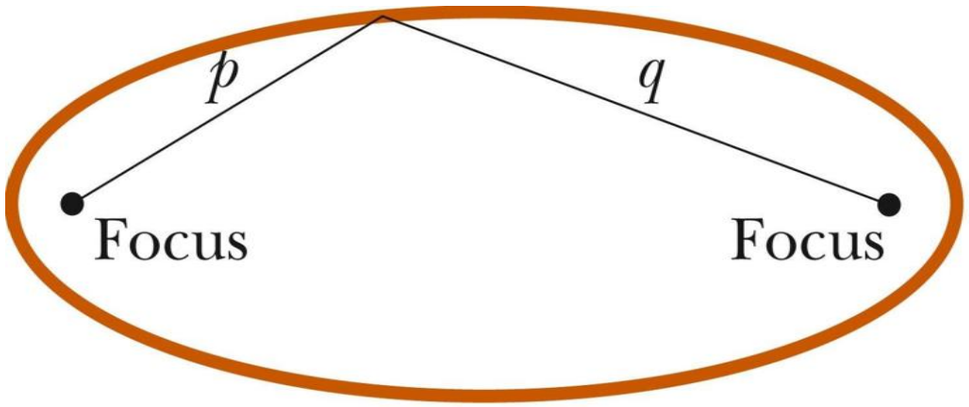
Escape speed:
The speed required for an object to leave a planet/large object such that it reaches an infinite distance with zero speed.

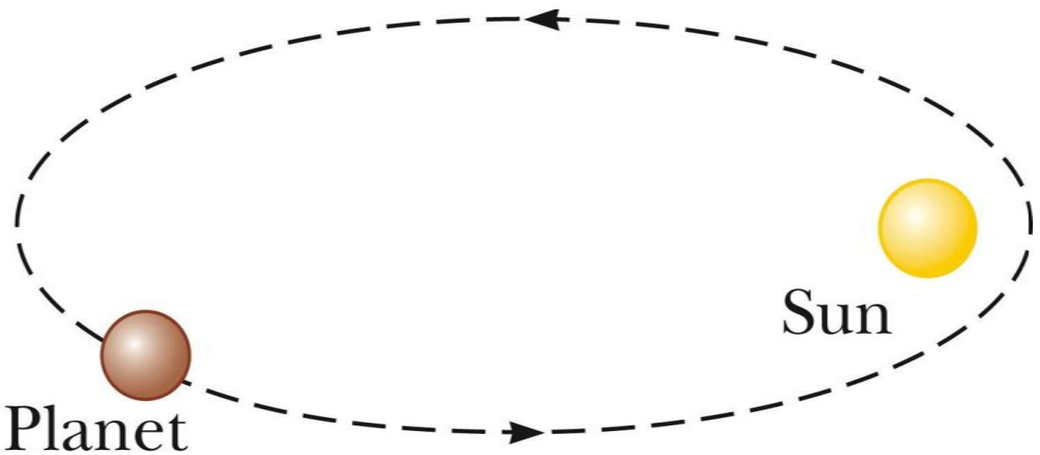
Escape speed tells us how fast something has to go to escape the gravitational force of the planet/object.

$$v_{\text{esc}} = \sqrt{\frac{2GM}{R}}$$

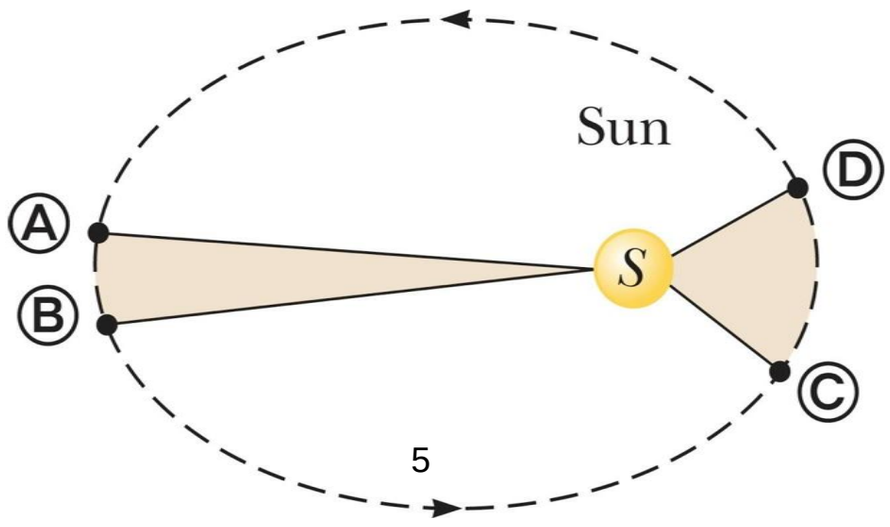
Kepler's first and second laws

Kepler's first law:
All of the planets move in elliptical orbits with the Sun at one of the focal points.





Kepler's second law:
A line drawn from the Sun to any planet sweeps out equal areas in equal time intervals.



Kepler's third law

Kepler's third law:
The square of the orbital period of any planet is proportional to the cube of the average distance of the planet from the Sun.

$$T^2 = \left(\frac{4\pi^2}{GM_S}\right) r^3$$

1. The orbital period of a planet equals the orbital circumference divided by the orbital velocity.

1. The square of the orbital period divided by the cube of the orbital radius is constant for all planets:

$$\frac{T^2}{r^3} = constant$$