Name Date

The Mass of the Sun

Orbits

The planets in our Solar System all orbit the Sun in elliptical orbits. Most planetary orbits are, however, almost circular. Since the planets are moving in circles they must be experiencing a centripetal acceleration.

We know that the centripetal acceleration on an orbiting body (e.g. a planet) is given by:

$$a = \frac{v^2}{r}$$

where *r* is the distance from the central body (e.g. the Sun), and *v* is the velocity it is moving at.

The centripetal acceleration is caused by the gravitational attraction of the two bodies, which is given by:

$$F = \frac{GMm}{r^2}$$

where *M* is the mass of the central body, *m* is the mass of the orbiting body, and *G* is Newton's Gravitational constant and is equal to 6.67 x 10^{-11} m^3 s^{-2} kg^{-1}

Since the centripetal acceleration is caused by the gravitational force, we use Newton's 2nd law:

$$F = ma$$

Putting the first two equations into the third one we therefore know that:

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

We can then work out a relationship between the velocity, the mass of the central object, and the orbital radius:

$$v^2 = \frac{GM}{r}$$

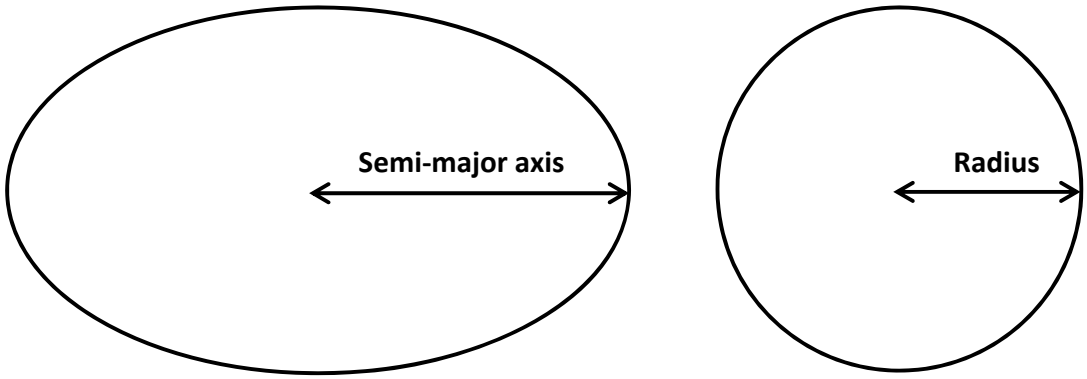
Name Date

Kepler's Laws of Planetary Motion

In 1605 Johannes Kepler wrote down three laws of planetary orbits:

1. The orbit of every planet is an ellipse with the Sun at a focus.
2. A line joining a planet and the Sun sweeps out equal areas during equal intervals of time.
3. The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

The semi-major axis of an ellipse is the half the longest diameter of the ellipse. In a circle, which has the same diameter all the way round. the semi-major axis is equal to the radius.



Can you work out which of Kepler's laws the last equation on the previous page corresponds to?
[*Hint: can you write the velocity around a circular orbit in terms of its period*]

Name Date

The Mass of the Sun

Using Kepler's 3rd law we can calculate the mass of the Sun based on the Earth's orbit. In fact, we can get roughly the correct answer using approximate numbers.

The Earth is 150 million km from the Sun and orbits once a year.

What is the velocity of the Earth around the Sun?

What is the mass of the Sun?

This is an extremely large number, and becomes very inconvenient to use. For this reason, astronomers normally use a different unit when measuring the mass of stars: the Solar Mass.

Can you use the same method to calculate the mass of the Earth from the orbit of the Moon?