Name: _____ Form: _____

GCSE

Astronomy

Club

2.3 Planetary Systems

Solar System Discoveries

a) Describe the contribution of Copernicus, Tycho and Kepler to our understanding of the Solar System

Copernicus' contribution: observed before the telescope was invented. Asserted that the Earth (+everything else) orbits the Sun. Didn't live to see the turmoil his work caused (vs. church). Man/Earth no longer at the centre of things. Observations seemed to confirm this and Galileo helped the idea secure theory. Copernicus also deduced that the Earth rotates.

Tycho's contribution: huge amount of accurate astronomical + planetary observations. Accurate enough for Kepler to use. He didn't believe the heliocentric model though, but is considered the last and possibly greatest naked eye astronomer. Also observed a supernova and a comet which helped discredit the Aristotelian idea of heavenly spheres. Employed Kepler.

Kepler's contribution: 3 laws of planetary motion (elliptical orbits) - first true 'laws'

1. Orbit of a planet/comet about the Sun is an ellipse with the Sun at one focus.
2. A line joining a planet to the Sun sweeps out equal areas in equal time intervals (fastest closest to the Sun)
3. The squares of the periods of the planets are ∝ to the cubes of their mean distance from the Sun

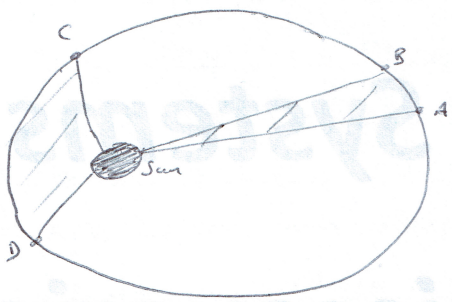
b) Illustrate Kepler's second law of planetary motion with the aid of a diagram

Kepler's second law of motion states that: an imaginary line joining a planet and the Sun sweeps out an equal area of space in equal amounts of time.

This means that: as the planet is closest to the Sun, the planet is moving fastest (and vice versa). The orbital radius and angular velocity of the planet in the elliptical orbit will vary.

Illustration of Kepler's second law of motion

windows2universe.org/the_universe/uts/kepler2.html



AB and CD areas equal + takes same time to go from A→B as C→D. Therefore, must go faster C→D as it is further.

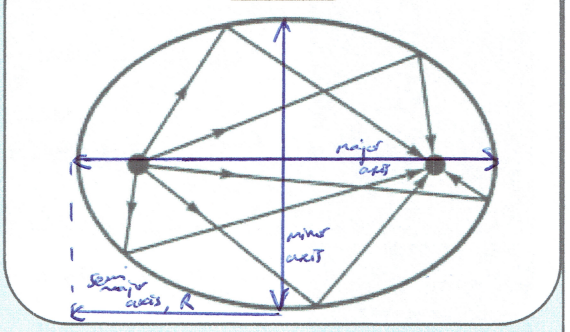
Animation:
commons.m.wikimedia.org/wiki/File:Kepler-second-law.gif

c) Demonstrate an understanding of Kepler's third law relating planetary distances to orbital periods and perform simple calculations using the formula: $T^2 = R^3$ where T is in years and R is in AU.

Draw and label the major axis and minor axis on the ellipse.
Explain what is meant by the semi-major axis, and label it R.

Explain, referring to the arrows already drawn on the diagram, what the significance is of the two foci of the ellipse: special points on the major axes (with Sun at one focus) where the distance between it and any point on the ellipse added to the distance between the other focus and the same point on the ellipse is always the same value

An ellipse



Calculate the orbital period of Mars, which has a semi-major axis of length 1.52366231 AU.

R= 1.52

T= ??

Equation: $T^2 = R^3$

Rearrange: $T = \sqrt{R^3}$

Insert values: $= \sqrt{1.52^3}$

Answer: T= 1.87 unit: years

Calculate the orbital period of Jupiter, which has a semi-major axis of length 5.20336301 AU.

R= 5.20

T= ??

Equation: $T^2 = R^3$

Rearrange: $T = \sqrt{R^3}$

Insert values: $= \sqrt{5.2^3}$

Answer: T= 11.86 unit: years

Calculate the semi-major axis of Neptune, which has an orbital period of 164.8 Earth-years.

R= ??

T= 164.8

Equation: $T^2 = R^3$

Rearrange: $R = \sqrt[3]{T^2}$

Insert values: $= \sqrt[3]{164.8^2}$

Answer: R= 30.06 unit: AU

Calculate the semi-major axis of ~~Neptune~~, which has an orbital period of 76 Earth-years.

R= ??

T= 76

Equation: $T^2 = R^3$

Rearrange: $R = \sqrt[3]{T^2}$

Insert values: $= \sqrt[3]{76^2}$

Answer: R= 17.94 unit: AU

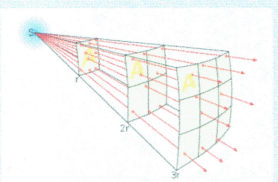
d) Recall the main astronomical discoveries of Galileo related to the Solar System:

Galileo's discovery relating to	Description of the discovery, in detail
Venus	1610 - planetary phases observed through a telescope, only compatible with the Copernican system - saw phases like the moon, could only be explained by Venus orbiting the Sun
The Moon	1609 - pointed his improved telescope at the moon - in depth study, drew the moon 30 Nov → 18 Dec - not a perfect sphere - valleys, plains + mountains - if the Earth wasn't the only imperfect sphere, might it belonged in the heavens too
Jupiter	1609/1610 - first objects to be found orbiting another planet - improved telescope, some things invisible to naked eye - slow to Ptolemaic world system - more than one centre of rotation - observed Jupiter for a month

e) Describe the discoveries of Ceres, Uranus, Neptune and Pluto and the techniques involved

Object discovered	Date of discovery and description of how it was discovered.
Ceres	1 January 1801, Giuseppe Piazzi, Palermo (re-found with help of Gauss + Olbers on 31 Dec 1801) Orginally considered a planet, and thought to fill the gap noticed between Mars + Jupiter. Pattern noticed in semi-major axes of planetary orbits – discredited Titius–Bode law 'Predicted' Uranus + methodical search began – Piazzi found a star → comet → Ceres
Uranus	13 March 1781, William Herschel, Bath Observed before but mistaken as a star, even Herschel thought it was a comet Used telescope of his own design in his garden Other astronomers realised + confirmed it was a planet
Neptune	23 September 1846 ← irregularities observed in orbit of Uranus Mathematically predicted – Urbain Le Verrier – and telescopic observations – Johann Gottfried Galle – confirmed it Confirmation of Newtonian gravitational theory Observed previously but not recognised.
Pluto	18 February 1930 Observations of Nephune suggest Uranus's orbit was being disturbed by something else too. Percival Lowell started an extensive search in 1906 (died 1916). Did find faint images in 1915 but not recognised. Widow's battle – search postponed until 1929 → Clyde Tombaugh systematically image the night sky in paired photographs

f) Demonstrate an understanding that gravity is the force responsible for maintaining orbits and its inverse square law nature.



Explain, using the idea of surface area of a sphere, how the effect of gravity behaves as the distance between two point sources of mass increases: The gravitational field is distributed equally in all directions around the sources. To find the strength at a point you would draw a sphere, of radius r. The strength at that radius is the source strength divided by the area of the sphere surface at that radius. Relationship between radius and sphere surface area is inverse square → $g \propto \frac{1}{r^2}$

Explain how the attractive nature of gravity causes an orbit to be maintained:

Newton's cannonball thought experiment → 'falling in a curve'

en.wikipedia.org/wiki/Newton%27s_cannonball