Name: _____ Form: _____

GCSE

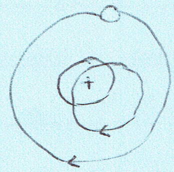
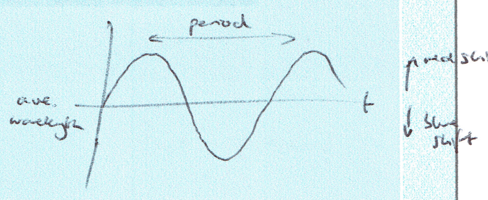
Astronomy

Club

2.4 Planetary Systems

Exoplanets

a) Describe how astronomers obtain evidence for the existence of exoplanets (including astrometry, transit observations and use of Doppler-shifts)

Observation Method	Description of method (Include a diagram)
Astrometry	Very precise measurement of the position of stars. A star with a planet will move in a tiny orbit itself, around a mutual centre of mass. Better at finding binary stars until Gaia is launched. Requires long observations if planetary orbits are large. 
Transit photometry observations	Uses light curves from stars, where the apparent brightness varies. Dips may indicate a planet crossing the face of the star in its orbit. Can only detect those planets whose orbits are aligned but can give an idea of a planet's mass. 
Doppler-shifts or radial velocity	If the position of a star wobbles due to the gravitational influence of a planet, this motion can appear to be moving away or towards the Earth. This movement would shift the wavelength of the star's radiation to the red or blue end of the spectrum and can be detected. 
One other method Direct imaging	Balance of glare vs. lack of reflection, so thermal emission used. Images in the infrared + with coronagraphs. upload.wikimedia.org/wikipedia/commons/9/97/A44226 main_exoplanet 20100414-a-full.jpg.

b) Discuss the difficulties associated with the detection of individual planets

Choose a few examples of exoplanets and discuss the difficulties associated with their detection. Explain which method was used to detect them and why.

Gliese 876 d / 581 e – both orbit the red dwarf, both detected by doppler shift/radial velocity. Radial velocity is the most productive planet hunting technique but is only of use to a distance of about 160ly (for Earth size planets). You also cannot observe multiple stars and it can only estimate a planet's minimum mass.

HD 209458 (first + water vapour) – Sun like star, confirmed by photometry (+spectroscopy). Can provide info about the planet's radius. Only works if aligned and a lot of false detections → Kepler mission.

VB 10b – still unconfirmed astrometry claim. Changes in stellar position are so small → Gaia will find many, but requires long observations (but will find those with larger orbits)

2M1207b – brown dwarf star, infrared imaging – thermal emission. Visible – too much glare or not enough reflection. Vague on mass + hard to distinguish from brown dwarfs but good on face-on-orbits + near orbits

c) Demonstrate an understanding that the presence of liquid water is probably an essential requirement for life

All life on Earth that we know of requires water to survive. The three most important properties of water are that it is a very good solvent, it is lighter as a solid than as a liquid and that it exists on Earth in all three states.

d) Describe the present theories about the origin of water on Earth

1. Planetary cooling - outgassed volatile components ~~were~~ held in an atmosphere of sufficient pressure for stabilisation + retention of liquid water.
2. Hydrate minerals - gradual leakage of water stored in Earth's rocks.
3. Volcanic activity - water vapour originating in eruptions condensing and forming rain
4. Extraplanetary - comets, TNOs, meteoroids & protoplanets (from the outer reaches of the asteroid belt) colliding with the Earth + bringing water with them. (likely a combination of these). The collision of a planetesimal like Theia may have helped the ongoing chemical reactions too.
5. Bacteria in the Early Ocean - produced hydrogen sulphide + CO_2

e) Describe methods used by astronomers to determine the origin of water on Earth (for example analysis of water on a comet by the Rosetta probe)

- Chemical analysis of moon rocks : Earth likely born with water - Split deuterised water ice asteroids which became part of Earth's raw material.
- Discovery of water vapour outgassing on Ceres - info related to the above.
- Vesta meteorites - suggest planetesimals (like Theia) could have had surface water.
- TNO + Comet isotope ratios - similar to oceanic water (but not perfect)
- Asteroid impurities - similar to oceanic water
- Rosetta probe + Comet 67P/Churyumov - Gerasimenko - isotope ratio not a good match (points to asteroids)

f) Demonstrate an understanding of the individual factors contained in the Drake Equation and their implications for the existence of life elsewhere in our Galaxy

The drake equation: $N = R_* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$ State what each term in the Drake equation refers to:

N = number of civilisations in galaxy with which radio communication may be possible. L = length of time such civilisations release those signals.

R_* = ave. rate of star formation in galaxy f_p = fraction of those stars that have planets n_e = ave. number of planets that can potentially support life per star that has planets. f_l = fraction of those that actually develop life f_i = fraction of those that go on to develop intelligent life f_c = fraction of those who develop technology that releases detectable signs of their existence into space.

Discuss how the uncertainty in the drake equations variables affects the likelihood of the existence of extra-terrestrial life:

Criticism of the equation mostly involves the fact that several terms are largely or entirely based on conjecture. Only rates of star formation and the incidence of planets have a sound theoretical + observational basis. The uncertainties involve our understanding of life, intelligence + civilisation, not physics, and no statistical parameters are possible for some of the parameters. The result is that the equation cannot be used to draw firm conclusions, and the margin of error is huge. It is hard to see it as meaningful other than to stimulate dialogue, especially around how to proceed experimentally (key) and what factors may affect the presence (or not) of ET. Figures from 0.01 to 5,000 have been published. (Drake + team estimated 10 in 1960.)

g) Demonstrate an understanding of the existence and significance of habitable zones/Goldilocks zones

The Goldilocks zone is an orbital range around a star where planet-like objects with sufficient atmospheric pressure can support liquid surface water. Also known as circumstellar habitable zone (CHZ). Bounds of the CHZ are calculated using the requirements of Earth's biosphere and its position in the solar system (and amount of solar radiant energy it receives). The CHZ is bounded by extremes, either too near or too far from a star. The nature of a CHZ is used to determine the likelihood of ET life.

It is called the Goldilocks zone because in the story of the 3 bears, one thing is always just right (Seal or Penidge). In astrobiology, it is equated with the habitable zone around a star where conditions could be just right for a planet to be capable of supporting life.

h) Describe some of the methods that astronomers use to obtain evidence for life (past or present) elsewhere in our Solar System

Method to obtain evidence for life	Description of the method.	Detects past or present life?
Studying surfaces	Telescope observation Lander experiments	Past + present
Examining meteorites	Chemical analysis	Past
Studying atmospheres	Spectroscopy Orbiters	Present

i) Discuss the possible benefits and dangers of discovering extraterrestrial life.

Benefits of discovering extraterrestrial life	Dangers of discovering extraterrestrial life
• Knowing we are not alone in the Universe would change the way we look at ourselves (could be bad!) • Knowledge of the Universe could increase dramatically • Potential to share technology eg. clean energy, or they may know how to cure illnesses or avoid global catastrophes	• If they are advanced, would they be friendly or assume subservience? • They may bring diseases we have no immunity to or our viruses may be deadly to them • Depending on aliens for knowledge could prevent our advancement • They may see humans/the Earth as a resource